BOOK 47
TAB# 1-50

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- history of lung disease
- Family history of LC
- genetics (eg Rb, P53 etc)
- Age of subject

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#11 Sidney

Report on a second retrospective mortality study in North-East England

PART I : Factors related to mortality from lung cancer, bronchitis, heart disease and stroke in Cleveland County, with particular emphasis on the relative risks associated with smoking filter and plain cigarettes

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Contents

Introduction to the whole report		5
Part I		
I.1	Introduction to Part I	12
I.2	The living sample	14
I.3	The decedent sample	16
I.4	Information obtained about the decedents and the living	18
I.5	Supplementary information from other sources	19
I.6	Statistical method and presentation of results	20
I.7	Problems in the interpretation of the results	24
I.8	Mortality by age, sex, social class and district	26
I.9	Mortality by some principal aspects of the smoking habit	30
I.10	Mortality of filter and plain cigarette smokers	
	a) Relative risk standardised for various characteristics	34
	b) Effect of biasses on the relative risk estimates	37
	c) Mortality by time of switch from plain to filter	40
	d) Discussion	41
I.11	Summary of main findings	46
Appendix A	Mortality by other aspects of the smoking habit	48
Appendix B	Mortality by some personal and environmental factors	56
Appendix C	Distribution of type of lung cancer found	64
Appendix D	Smoking habits according to the relative compared with those according to the decedent	68
Appendix E	Details of statistical method	70
Appendix F	Supplementary tables	74
Index to Tables		88
References		92
Tobacco Research Council Research Papers and Occasional Papers		94

Introduction to the whole report

A. Background

In 1963 a retrospective study was carried out in the Teesside area with the objective of obtaining information about the main factors thought likely to be associated with lung cancer and bronchitis mortality. The report on the study, which gave particular attention to evaluating the relative associations that smoking and exposure to air pollution have with mortality from these causes, was published as Tobacco Research Council Research Paper No. 8 "Report on a study of environmental factors associated with lung cancer and bronchitis mortality in areas of North-East England" by A.J. Wicken and S.F. Buck.

In 1972 it was decided to go back to the area and to carry out a second retrospective study. This second study, which was carried out in 1973, is described in this Research Paper.

In the intervening ten years a development took place which had a particular bearing on the methods and objectives of the second study. This was the marked change which occurred in the pattern of smoking habits in the United Kingdom (Lee, 1976). In 1963 only 33% of cigarettes smoked had filters, the rest being plain. This percentage, which had risen from as little as 1% in 1953, continued to rise until, by 1973, it had reached 83%. Associated with this switch to filter cigarette smoking there was, as shown in Table 1, a marked drop in the average tar level of cigarettes smoked.

TABLE 1

Trends in tar yields between 1963 and 1973 in the United Kingdom

Year	Filter cigarettes		Plain cigarettes		All cigarettes
	% sales	Mean tar	% sales	Mean tar	Mean tar
1963	32.8	n.a.	67.2	n.a.	n.a.
1965	53.0	29.3	47.0	35.0	31.4
1967	65.9	23.2	34.1	32.6	26.0
1969	75.5	21.8	24.5	30.3	23.9
1971	79.8	19.8	20.2	27.7	21.3
1973	83.0	17.4	17.0	24.6	18.7

Note: n.a. = data not available

The first objective of the second study, therefore, was to see whether a smoker of filter cigarettes is less at risk of dying from one of four diseases associated with smoking than an otherwise equivalent smoker of plain cigarettes.

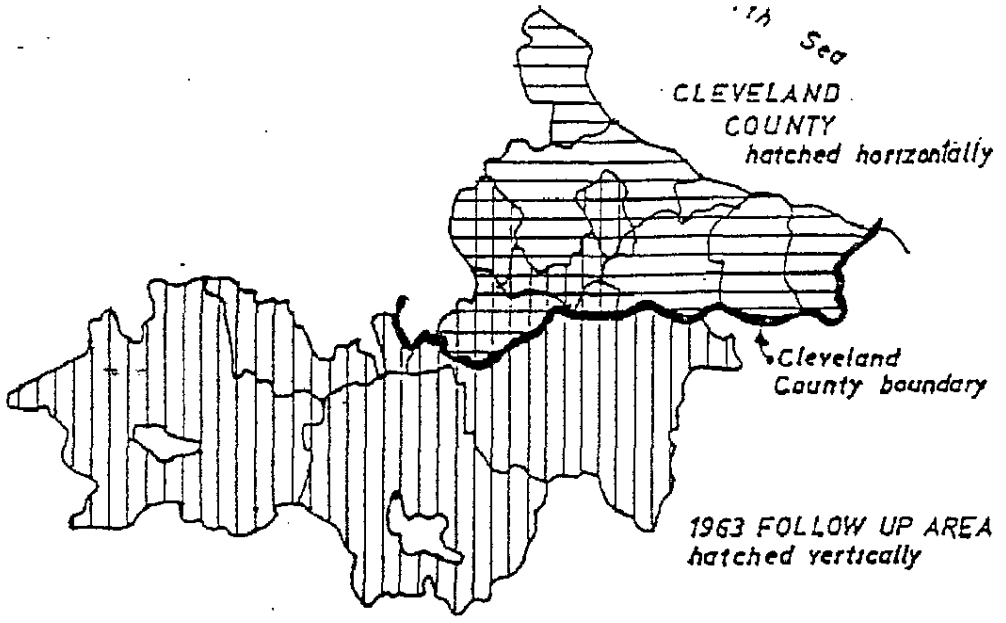
The second objective was to determine the changes that had occurred in mortality from lung cancer and bronchitis since 1963 and to attempt to relate these to changes that had occurred in the smoking habits of the population and in air pollution levels.

C. The study area

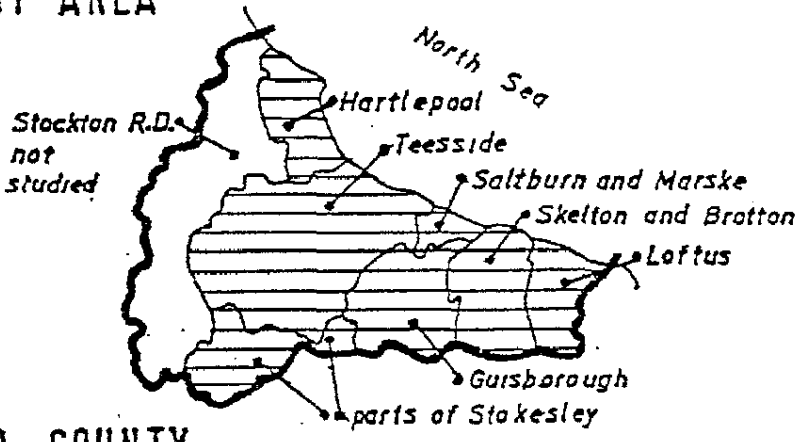
Since 1963 some changes had also occurred in the names and boundaries of the local government areas in and around the original study area. In 1963 the study had been carried out in six areas, namely Eston U.D., Stockton-on-Tees M.B. and a group of four rural districts (Croft R.D., Northallerton R.D., Richmond R.D. and Stokesley R.D.). In 1968 Eston U.D., Stockton-on-Tees M.B. and part of Stokesley were merged with various districts (including Middlesbrough) to form Teesside C.B. In 1974 Teesside C.B. was combined with Hartlepool C.B., four urban districts (Guisborough U.D., Loftus U.D., Skelton and Brotton U.D. and Saltburn and Marske-by-the-Sea U.D.), Stockton R.D. and a further part of Stokeley to form the new Cleveland County.

To meet the second objective of the study it was clearly necessary to restrict ourselves to the original 1963 study area. However, for research on the first objective it was decided to cover the whole of Cleveland County as it was of a suitable size, clearly defined and likely to remain unchanged for many years. In the event, however, the study area excluded Stockton R.D. which was in fact incorporated in the new county when it was set up in 1974. Thus, although we refer in the text subsequently to "Cleveland County" we really mean the somewhat smaller area actually covered. As Stockton R.D. contains less than 4% of the total population of the county, omitting it can only have a marginal effect at most.

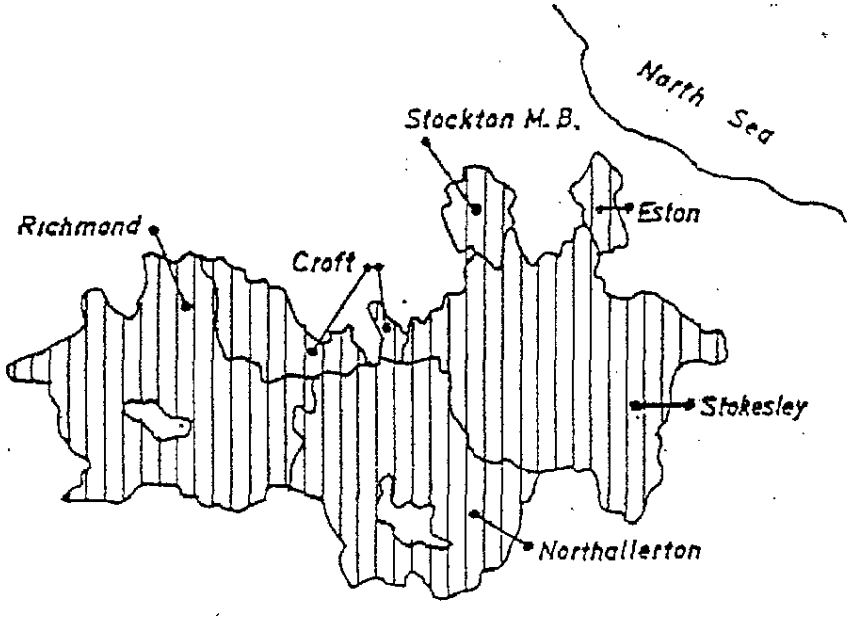
Map 1 illustrates the total area covered in 1973, map 2 the area relevant to the first objective and map 3 that relevant to the second.



1. 1973 STUDY AREA



2. CLEVELAND COUNTY



3. 1963 FOLLOW UP AREA

D. Outline of study method

The method used for the 1973 study was essentially the same as that used in 1963. Relatives of decedents from the diseases of interest were interviewed and information obtained as to the smoking habits and other relevant characteristics of the decedents. This information was compared with that obtained from a control sample of the living population.

Under the first objective it was decided to study mortality from coronary heart disease and cerebrovascular disease in addition to lung cancer and chronic bronchitis. Deaths in Cleveland County occurring in the few years immediately preceding the study were covered.

For the second objective attention was focussed on deaths from lung cancer and chronic bronchitis occurring over the whole period from 1963 to 1972 in the 1963 study area.

The information obtained in the study was supplemented by additional data obtained from three other sources. Firstly, data on air pollution from 1964 to 1973 were obtained from Cleveland County Council. Secondly, as a check on changes in habits that had occurred in recent years, regional smoking data for 1969 to 1972 were obtained from Imperial Tobacco Limited. Thirdly, information on the lung cancer decedents was provided for us, where available, from hospital records, not only as to the histological type of the lung cancer, but also as to what the decedents had said they had smoked when they were in hospital.

E. The two parts of the report

Although there is some degree of overlap of data, both on decedents and on living controls, relevant to both objectives, it is convenient to consider them separately in the report. The first part of the report, "Factors related to mortality from lung cancer, bronchitis, heart disease and stroke in Cleveland County, with particular emphasis on the relative risks associated with smoking filter and plain cigarettes", is presented in this volume, and deals with the first objective.

The second part of the report, "Changes in lung cancer and bronchitis mortality and in other relevant factors occurring in areas of North-East England 1963-1973", will be published as a separate volume and will cover the second objective.

In addition to giving the findings of the study, the separate parts of the report give fuller details of the methodology used than those given in section D above.

F. Acknowledgements

This study would not have been possible without the help of the Medical Officers of Health and Community Physicians of Cleveland. We wish to thank Dr. R.J. Donaldson, the former Medical Officer of Health of Teesside County Borough and Dr. H.H. John, who is now Area Medical Officer. We would also like to thank the three Cleveland District Community Physicians, Dr. Peter Burrell, Dr. H.C. Milligan and Dr. J. Tolland as well as Dr. Brendan Rohan, a former District Medical Officer of Health, and the late Dr. Hugh Morrison of Richmond. We are also greatly indebted to Mr. K.G. Coates, who was in charge of the Research Division of Teesside Health Department, and the Chief Environmental Health Officers - Mr. R. Emmerson, Mr. R. Love, Mr. F. Sugden and Mr. J. Hill. Mr. Hill, in his capacity as Chairman of the Co-ordination of Air Pollution and Noise Officer Group, provided us with the air pollution data. Mr. K.P. A'Court of Imperial Tobacco Limited supplied estimates of cigarette consumption for Cleveland County.

Dr. Michael Walton, Consultant Chest Physician, Poole Hospital, greatly assisted the research by making records available to us, and Miss M. Waddington extracted additional data for the lung cancer patients from the hospital records with the co-operation of the local pathologists. We would also like to thank Mrs. Corrigan and the staff of the Cancer Register, Newcastle.

The first study on mortality of lung cancer and bronchitis in the Teesside area took place in 1963 at the suggestion of Mr. J.E. Ginty, M.B.E., J.P., then Chairman of the Eston U.D.C. Environmental Health Committee and Vice Chairman of the Area Health Authority during the time of the present study.

Finally, we acknowledge gratefully the considerable help given to us by Mrs. B.A. Forey in carrying out the statistical analysis and by Miss J. Barnard and Miss C. Kerby who patiently typed the numerous drafts of this report.

[illegible] lung cancer, bronchitis, heart disease and stroke in Cleveland County, with particular emphasis on the relative risks associated with smoking filter and plain cigarettes.

I.1 Introduction to Part I

As indicated in the introduction to the report as a whole, the study was carried out, in 1973, by interviewing relatives of those who had died in Cleveland County from the four diseases of interest, obtaining information as to the smoking habits and other relevant characteristics of the decedents, and comparing it with that obtained from a control sample of the living population. Sections I.2 to I.4 describe the methodology used for the collection of these data.

Section I.5 gives details of the sources and nature of the supplementary information which was collected. The statistical method used for the analysis of the results is described in section I.6, while section I.7 comments on problems that exist in interpreting the results correctly.

Section I.8 gives the findings relevant to variations in mortality from the four diseases that are associated with four principal factors; age, sex, social class and district within Cleveland County. Information on mortality analysed according to three aspects of the smoking habit (amount smoked, depth of inhalation and age of starting to smoke) is presented in section I.9.

Following these two sections, which were intended to give essential information on major factors which could well differ systematically between filter and plain smokers, and which, if ignored, might bias the critical comparison, section I.10 analyses and discusses in detail the findings relevant to smoking filter or plain cigarettes. This section, supplemented by a summary of the main findings in section I.11, concludes the main text of Part I of this Research Paper.

In order to bring out clearly the arguments leading to the conclusions relevant to the filter/plain comparison, we have tended to avoid giving in the main text detailed results on aspects of the data not of central importance in this comparison. However, as many of these

additional findings are of interest in themselves, the main text is supplemented by six appendices given at the end of Part I.

Thus Appendix A, which is an extension to section I.9, gives a more detailed look at mortality in relation to the smoking habit, while Appendix B relates mortality to the other personal and environmental factors we studied. Appendices C and D summarise the additional data obtained on the lung cancer decedents, the former giving the distribution of type of lung cancer found while the latter relates smoking habits as given by the relative to those given by the decedents when in hospital. Finally, following Appendix E, which extends the statistical method section I.6, a number of detailed supplementary tables are given in Appendix F.

The information concerning the living population was obtained by means of personal interviews in samples of households. In each household one resident aged over 16 was interviewed and asked questions about himself and about all other people aged over 16 resident at that address.

The households were selected by a random sampling method from the electoral registers. A relatively large proportion was sampled in the areas previously covered in the 1963 survey so as to provide adequate bases for separate analysis. Of 5,570 addresses originally selected in the total study area (Cleveland County plus Rural Districts) 302 were found to be unoccupied. Of the 5,268 occupied addresses interviews were obtained at 4,925, a response rate of 93%. At these addresses information on 10,025 people was collected, an average of 2.04 people per household.

For this part of the report data from the Rural Districts outside Cleveland County were ignored, as were data on living people under 35, there being no comparable information available on decedents of this age group. This left 2,666 males and 3,039 females. Eliminating 103 males and 58 females who did not state their smoking habits and also a further 23 females who smoked tobacco products other than manufactured cigarettes (a number too small for valid study), the living population finally studied consisted of 2,563 males and 2,958 females.

The distribution of the living population by age is given in Table 2 and by district in Table 3. In each table the estimates obtained from the 1971 10% census are presented for comparison and the proportion sampled given. As can be seen the proportions sampled, which overall are 2.2% (males) and 2.3% (females), do not differ markedly by age, though of course they do by district, due to the varying sampling fractions used for the reasons stated above.

TABLE 2

Living population by age at interview and sex

Age group	Male			Female		
	No. in sample	Census estimate	% sampled	No. in sample	Census estimate	% sampled
35-44	750	34,270	2.2	800	33,110	2.4
45-54	785	33,530	2.3	795	32,420	2.5
55-64	550	26,400	2.1	593	28,250	2.1
65+	478	20,930	2.3	770	33,020	2.3
Total	2,563	115,130	2.2	2,958	126,800	2.3

TABLE 3

Living population by district and sex

District	Male			Female		
	No. in sample	Census estimate	% sampled	No. in sample	Census estimate	% sampled
Eston	422	7,230	5.8	485	7,570	6.4
Stockton	425	18,370	2.3	485	20,460	2.4
Ex-Stokesley	165	5,540	3.0	208	5,960	3.5
Rest of Teesside	820	52,260	1.6	949	57,900	1.6
Hartlepool	454	20,670	2.2	513	23,190	2.2
Urban Districts	277	11,060	2.5	318	11,720	2.7
Total	2,563	115,130	2.2	2,958	126,800	2.3

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(Note: i) The first four districts comprise Teesside C.B.

ii) Ex-Stokesley is that part of the area formerly Stokesley R.D. that is now in Cleveland County

iii) The urban districts comprise Guisborough U.D., Loftus U.D., Skelton and Brotton U.D., and Saltburn and Marske-by-the-Sea U.D.)

Decedents were classified by cause of death solely on the information available on their death certificates. The causes of death studied and the periods and age ranges covered are listed in Table 4.

The definition of cerebrovascular disease (stroke) for the purpose of this study did not include subarachnoid haemorrhage (I.C.D. 430).

An initial list was compiled for the whole study area of those who appeared to have died of the diseases covered by the survey within the relevant period. Doubtful cases were then excluded under the supervision of one of us (G. Dean). Table 5 gives by cause of death and sex the numbers finally listed relevant to the Cleveland County part of the study. From the total of 3,145 decedents listed for all causes and both sexes, interviews were obtained from relatives of 2,642 (84.0%). After excluding, as for the living population, some decedents for whom no information on smoking habits was available and also some females who were said to have smoked tobacco products other than manufactured cigarettes, a total of 2,370 decedents was available for study, 75.4% of those listed.

TABLE 4

Decedents studied in Cleveland County

Sex	Age range	Cause of death	I.C.D.	Period
Male	35+	Lung Cancer	162	1970-1972
Female	35+	Lung Cancer	162	1969-1972
Male	35+	Chronic Bronchitis	490-493	1970-1972
Female	35+	Chronic Bronchitis	490-493	1969-1972
Male	35-64	Coronary Heart Disease	410-414	1971-1972
Male	35-64	Cerebrovascular Disease	431-438	1966-1972

(Note: I.C.D. numbers quoted refer to the International Classification of Disease, the 8th Revision)

TABLE 5

Success rate for following up decedents

Cause of death	Sex	Number of deaths		Studied as % of listed
		Listed	Studied	
Lung Cancer	Male	780	616	79.0
	Female	199	150	75.4
Chronic Bronchitis	Male	721	530	73.5
	Female	295	218	73.9
Coronary Heart Disease	Male	753	571	75.8
Cerebrovascular Disease	Male	397	285	71.8
Total		3,145	2,370	75.4

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Questions about smoking were asked in two parts. In the first part information was obtained as to whether the decedent or the living person smoked at the time of death or interview respectively ("current smoker"), whether he had given up previously ("ex-smoker") or whether he had never smoked ("never smoker"). Further information about current smokers and ex-smokers was then obtained as follows:-

a) when started to smoke regularly

b) when gave up (ex-smokers only)

c) whether at time of death or interview (current smokers) or at time of giving up (ex-smokers) they then smoked:

i) manufactured cigarettes, and if so filter-tipped or plain

ii) hand-rolled cigarettes

iii) pipe or

iv) cigars

and if so how many per day (cigarettes) or week (pipe or cigars).

The second part of the smoking questions consisted of a detailed history. Questions about current smokers were asked relevant to the last 2 years, 3-5 years, 6-10 years or more than 10 years before death or interview, and questions about ex-smokers were similarly asked for these four periods before giving up. The questions related to the number of manufactured cigarettes smoked per day and whether they were mainly plain, mainly filter or about equal; the number of hand-rolled cigarettes smoked per day; the number of ounces of pipe tobacco per week; the number of cigars smoked per week and the number which were miniature, small, medium or large size; and the depth of inhalation of smoke from each type of product ("a lot", "a fair amount", "just a little" or "not at all").

Information was also obtained on other variables thought to be of possible relevance to one or more of the causes of death studied. These variables were: social class; occupation; exposure to dust or fumes; presence of morning cough; having had a close relative dying previously of one of the four causes of death studied; obesity index; exercise; consumption of tea or coffee and frequency of alcohol consumption. The ranges of possible answers are not listed here as they will become clear later in the text, when the possible effects of these variables on mortality are considered, mainly in Appendix B.

Copies of the questionnaires used are available on request from the Tobacco Research Council.

I.5 Supplementary information from other sources

The information obtained from the interviews was supplemented by four sets of data taken from other sources.

Firstly, from the results of their Annual Consumer Survey (on which the Tobacco Research Council's Research Paper No. 1 "Statistics of Smoking in the United Kingdom" is based), Imperial Tobacco Limited were able to supply us with information on filter and plain smoking habits relevant to the Cleveland area for each of the years 1969 to 1973. This information, based on an average of 295 interviews each year of cigarette smokers aged 35 or over, gave the number of filter and plain smokers by age, sex and number of cigarettes smoked.

Secondly, by reference to data made available to us from hospital records, those stated on their death certificates to have died from lung cancer were classified, where possible, as having had histologically and/or cytologically confirmed squamous carcinoma, oat or small cell carcinoma, adenocarcinoma or other types of lung cancer.

Thirdly, the smoking habits as reported by the lung cancer decedents when they were in hospital were provided, where available, from the hospital notes. This information could be used to classify the decedents as smokers of manufactured cigarettes, hand-rolled cigarettes, pipes or cigars or as non-smokers or ex-smokers and to classify the manufactured cigarette smokers by number smoked and whether they had recently reduced, but the hospital records did not distinguish between filter and plain smoking.

Fourthly, information was obtained on air pollution. As Part II of this Research Paper is more concerned than this part with air pollution, full details of the data available on air pollution and its sources are given there. For the purposes of this part, addresses (within Teesside C.B. only) were classified as being in areas of high, medium or low pollution based on data provided by Teesside C.B.

a) Introduction

In prospective studies the relative risk (r) of death from a disease for those with a particular factor compared with those without it can be calculated by:

$$r = \frac{\text{proportion of factor positives who die in the study period}}{\text{proportion of factor negatives who die in the study period}}$$

If n_1 and n_2 are the number at risk, d_1 and d_2 are the number dying with the disease in the study period and the subscripts 1 and 2 refer respectively to those factor positive and factor negative, this relative risk is given by

$$r = \frac{d_1/n_1}{d_2/n_2}$$

Provided the total mortality rate is small, r can be also estimated accurately enough for most practical purposes by substituting survivors (s) for number at risk given

$$r = \frac{d_1/s_1}{d_2/s_2}$$

Clearly this expression can be rewritten as

$$r = \frac{d_1/d_2}{s_1/s_2}$$

i.e. $r = \dfrac{\text{ratio in decedents of factor positives to factor negatives}}{\text{ratio in survivors of factor positives to factor negatives}}$

This is the basis of the retrospective study method. Provided unbiassed estimates of both the numerator and denominator of the above expression can be obtained, a good estimate of relative risk can be computed.

b) Inadequacy of an overall 2 x 2 table

If the factor being studied was the only factor relevant to death from the disease of interest, or if the distribution of factor positives and factor negatives was identical with regard to any other relevant factor, then the relative risk could be estimated adequately from a single 2 x 2 table and its significance calculated by a simple χ^2-test on 1 degree of freedom.

In practice this is rarely the situation. If it is not, an estimate based on a single 2 x 2 table can be quite inaccurate. To illustrate this consider the following hypothetical data:

	Age 45-54		Age 55-64	
	Factor +	Factor -	Factor +	Factor -
Decedents	25	50	200	100
Living	50	100	100	50

Within each age group separately, the estimated relative risk is 1, and there is therefore no apparent effect of the factor. However, let us combine the results into a single table:

	Factor +	Factor -
Decedents	225	150
Living	150	150

A relative risk of 1.5 is now apparent. This biassed answer occurs because both the death rate and the proportion of factor positives in the living depend strongly on age.

Clearly, therefore, in attempting to assess the effect of the factor accurately one must take into account, or standardise for, confounding factors, such as age in the example above.

Basically, there are two methods of carrying out this standardisation. The first is to fit a mathematical model simultaneously relating the probability of being a decedent or a survivor to the presence or absence of all likely influencing factors. While this approach allows a simultaneous study of more factors than the second method, as it avoids the problem inherent in the second method with small numbers in cells, it has two disadvantages. One is that the result one obtains relevant to the significance of a particular factor may depend on the particular form of the mathematical model used. It is often difficult to find any one model which fits all the data adequately or to demonstrate that one model is significantly superior to another. The other disadvantage is that this method involves very large amounts of computer time.

The second method, and the one we used, was to subdivide the overall 2 x 2 table into a number of 2 x 2 sub-tables, each separate sub-table reflecting the relationship between the factor of interest and the disease for a particular set of values of chosen standardising variables. Thus if one wished to study the relationship of filter and plain smoking to lung cancer, and one considered age, number of cigarettes smoked and level of inhalation to be possible confounding variables, one might construct the 48 2 x 2 sub-tables relevant to each combination of 4 levels of age, 3 of number smoked and 4 of level of inhalation (say).

The problem of analysis is thus reduced to evaluating a simultaneous estimate of relative risk based on a number of 2 x 2 sub-tables. Maximum likelihood methods, described in detail in Appendix E were used to estimate a single value of r best fitting all the sub-tables. The log-likelihood for this solution L_R was then compared with L_1, the log-likelihood for the null hypothesis r = 1 and L_{MAX}, the log-likelihood for the case where a single best fitting r is calculated individually for each 2 x 2 sub-table. If a 2 x 2 sub-table had either no decedents, no living subject, no person factor positive or no person factor negative, it was not considered in the analysis at all as it could contribute no useful information.

By treating $2(L_R-L_1)$ as being distributed approximately as χ^2 on 1 d.f. (degrees of freedom) it was possible to test whether, over all sub-tables, the fitted value of r differs significantly from 1. This tests the significance of r.

By treating $2(L_{MAX}-L_R)$ as being distributed approximately as χ^2 on N-1 d.f., where N is the number of 2 x 2 sub-tables contributing useful information, it was possible to determine whether it is valid to take the fitted value of r as applying consistently to all the sub-tables. For example, it may be the case that a particular factor strongly affects mortality in the young but less so or not at all in the old. This tests the consistency of r.

It should be noted that, for the method of analysis to work, the sub-division of the data into 2 x 2 sub-tables should not be too fine. If it is, then not only will a great number of the sub-tables have to be

rejected as producing no useful information, with a consequent loss of a sizeable proportion of the data but the approximation of our test of consistency to χ^2 will be very poor.

d) Presentation of results

When investigating many of the factors we calculated relative risks for a number of possible combinations of standardising factors. For example, for the tables in Appendix B, we computed unstandardised relative risks together with those standardised for a, a+s, a+c, a+d, a+s+d and a+s+c where a is age, s is smoking group, c is social class and d is district using the 4 levels of a, 6 of c, 6 of d and 7 of s used in Tables 7 and 8. It would have been very space-consuming and not particularly informative to present all these results in this report. Nor would it have made the findings easy to follow had we given the actual numbers dying of each cause and those in the living population in the tables in the main text. It was therefore decided that we would present the results of the relative risk analyses as follows:

i) in the main tables given with the text, present simply the relative risks by level of the factor being considered standardised by one single most useful combination of standardising factors (usually a+s) together with an indication of the significance of the quoted relative risks,

ii) in Appendix F, give the numbers dying from each cause and those in the living population by level of each factor considered in the main tables and

iii) in supplementary tables, available on request from the Tobacco Research Council, present all the calculated relative risks together with the results of the tests for consistency.

In the presentation of the significance of relative risks in the main tables, asterisks have been used as follows:

* = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$, **** = $p < 0.001$

Relative risks based on five deaths or less are bracketed.

If standardisation for additional factors markedly altered the estimate given in the main tables, this is noted in the text.

Appendix F also gives detailed findings for some results too extensive, or not important enough, to be presented as main tables. They are referred to in the text as appropriate.

Problems in the interpretation of the results

The essence of our study method, as we have seen, lies in the comparison of two estimates of the proportion of people positive for a particular factor of interest, one relevant to decedents from the disease of interest and one relevant to the living population. There are two main reasons why the estimate of relative risk obtained might not match that which would have been obtained from a prospective study.

The first of these lies in the fact that the estimates obtained relevant to the decedents may be biassed because the relative

a) never knew accurately about the fact of interest

b) could not now remember due to the time that had elapsed since the death or

c) consciously, or subconsciously, misrepresented the situation because of knowledge or suspicion about the relationship of the factor to the death.

Inasmuch as some of the answers for the living population were obtained second-hand, the first of these three objectives applied partly to the estimate obtained relevant to the living population. To simplify the text later, we refer to bias from these sources as recall bias.

The second main reason is that the answers for the living population, apart from the smoking history questions, are relevant to the situation at the time of interview, i.e. 1973, and are not necessarily the same as would have been obtained had the interviews taken place when the decedents died. If there had been a marked change in the living population in the proportion of people factor positive between the average time of death of the decedents and 1973 then a markedly skewed estimate of relative risk might be obtained. We refer to this later as time bias.

As we explain in the discussion of the results for the filter/plain comparison (section I.10) no retrospective method can be free of suspicion of bias. However, there are methods available of checking the likely extent of, and in some cases correcting for, these biasses.

Information on recall bias was obtained in two ways. Firstly, comparison was made in the living population of those answers obtained

from the person himself with those obtained second-hand. Secondly, the information on the smoking habits of the decedents obtained from relatives was compared with that given by the decedents themselves taken from the hospital notes.

Correction for time bias in smoking habits was also possible in two ways. Firstly, the smoking history answers to the questionnaire in the living population could be used to gain information on smoking at a time comparable to that to which the data on the decedents referred. Secondly, the separate survey data supplied by Imperial Tobacco Limited could be used to judge the extent of changes in the smoking habits of the population in the years preceding the survey.

The results obtained are mainly relevant to the section (I.10) concentrating on the filter/plain comparison, as consideration of these biasses, especially the time bias, is particularly relevant there.

I.8 Mortality by age, sex, social class and district

In subsequent sections we assess the relationship between the four causes of death studied and a number of factors, including both many aspects of the smoking habit as well as a variety of personal and environmental variables. In order to do this sensibly, it is necessary to standardise for some or all of certain important variables. The present section, and the next, are concerned as a preliminary with illustrating the relationship of the standardising variables themselves to mortality. This section deals with age, sex, social class and district, while section I.9 considers three main features of the smoking habit.

The distribution of the number (N) of decedents by age and sex is given in Table 6, which also presents estimated mortality rates per 100,000 per year in Cleveland County (MC) and compares it with the corresponding rate for the same years of death in England and Wales (ME). MC is estimated by the expression $MC = (100{,}000 \times D)/(A \times Y \times F)$ where D is the observed number dying, A is the 1971 census estimate of population taken from Table 2, Y is the number of years studied and F is the ratio of deaths studied/listed. ME was computed from the Registrar General's estimates by combining figures for the appropriate years.

The results in Table 6 illustrate that in Cleveland County the trends by age and sex of the causes of death match fairly closely the national trends, though the absolute levels of chronic bronchitis and coronary heart disease are somewhat above the national average. The sex ratio of the death rates for the two diseases studied in both sexes is very large, being about 5.8 to 1 for lung cancer and about 3.6 to 1 for chronic bronchitis. As the sex ratios are so large, and as they vary considerably with age, rising from about 2.5 to 1 for 35-44 year olds up to almost 5 to 1 for bronchitis and 9 to 1 for lung cancer for those over 65, it was necessary, in any analyses of these two causes of death, to consider men and women separately.

Table 7, which summarises the relative risks associated with the various levels of each of the three factors, age (unstandardised) and social class and district (standardised for age and smoking), illustrates further the strength of the age relationship. Although it is most marked for chronic bronchitis, rates for which rise by over 100-fold for men and over 50-fold for women between 35-44 and 65+, it is still highly

TABLE 6

Deaths studied by age at death, sex and cause of death

Cause of death (Years covered)	Sex		Age group 35-44	45-54	55-64	65+	Total*
Lung Cancer	Male	N	14	85	216	301	616
(1970-1972)		MC	17.2	107.0	345.2	606.8	225.8
		ME	13.1	80.1	288.5	597.7	228.5
Lung Cancer	Female	N	7	27	48	68	150
(1969-1972)		MC	7.0	27.6	56.3	68.3	39.2
		ME	5.6	23.8	52.4	77.0	42.7
Chronic Bronchitis	Male	N	6	28	96	400	530
(1970-1972)		MC	7.9	36.9	164.9	866.7	208.8
		ME	3.3	26.1	138.8	649.5	185.8
Chronic Bronchitis	Female	N	3	12	32	171	218
(1969-1972)		MC	3.1	12.5	38.3	175.2	58.2
		ME	2.2	10.6	30.2	135.5	51.5
Coronary Heart	Male	N	43	190	337		570
Disease (1971-1972)		MC	82.8	373.8	842.0	-	399.1
		ME	66.8	281.2	722.7		349.7
Cerebrovascular	Male	N	18	78	189		285
Disease (1966-1972)		MC	10.5	46.3	142.4	-	60.2
		ME	6.1	31.3	144.5		58.1

Note : N = number of deaths studied

MC = estimated mortality rate per 100,000 in Cleveland County

ME = estimated mortality rate per 100,000 in England and Wales

* Totals refer to ages 35+ for lung cancer and chronic bronchitis, and to 35-64 for coronary heart disease and cerebrovascular disease.

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[illegible] for each of the other causes of death. This indicates the clear necessity of standardising for age in analyses of the association of any other factor to mortality from any of the causes of death.

Variations in mortality by social class are in general of smaller magnitude than those by age but there are nevertheless a number of significant results. Chronic bronchitis shows most variation by social class of the four causes of death studied, rising in both sexes by a factor of 3 or 4 to 1 between social classes I and II combined and social class V, with much greater mortality rates still in the "other" group, which is mainly composed of the unemployed, disabled and retired. Of note also for bronchitis is the marked excess death rate of housewives as compared with working women. This could perhaps be partly artefactual inasmuch as women with bronchitis may have given up employment prematurely to work at home and been classed as housewife rather than "other". There is little variation in mortality by social class for either lung cancer or heart disease though, if anything, the trends favour the higher social classes, significant differences being noted in women for lung cancer in social classes I and II (below average) and in men for heart disease in class V (above average). For stroke, there is a clear 2-fold excess mortality in class V but no other significant difference.

Mortality also varies significantly by district for some of the causes of death. As compared with the rest of Teesside death rates tend to be higher in Eston, similar in Stockton, somewhat below average in the Urban Districts and lower still in the rural area "ex-Stokesley", especially for chronic bronchitis. Hartlepool is somewhat anomalous inasmuch as while death rates are similar to the rest of Teesside in four cases they are significantly below average for lung cancer in men, and significantly above average for chronic bronchitis in women.

As noted in section I.6 in the analyses of the factors considered in later tables, relative risks were calculated standardising for social class or district in addition to the more important factors of age and smoking. However, in general the relative risk estimates obtained were similar to those standardised for age and smoking only. In view of the results in this section this is perhaps not surprising as it would have needed the two groups being compared to have very different social class or district distributions for standardisation for these factors to have much effect on the magnitude of the estimate of relative risk.

TABLE 7

Relative risks of mortality by age (unstandardised), by social class and by district (standardised for age and smoking level)

Factor studied /Level of factor	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
AGE						
35-44	0.17****	0.22****	0.24****	0.24****	0.26****	(0.25**)
45-54 (Base)	1.00	1.00	1.00	1.00	1.00	1.00
55-64	3.63****	4.89****	2.52****	3.46****	2.38****	3.58****
65+	5.82****	23.46****	-	-	2.60****	14.71****
SOCIAL CLASS						
I + II	1.01	0.36***	0.95	0.96	(0.28**)	(0.45)
III (Base)	1.00	1.00	1.00	1.00	1.00	1.00
IV	1.08	1.24	1.15	0.84	0.81	2.28
V	1.13	1.49**	1.39**	2.33****	0.97	1.55
Other	1.38*	4.26****	1.05	1.06	0.70	7.43****
Housewife	-	-	-	-	0.81	3.58****
DISTRICT						
Eston	1.60***	1.32*	1.80****	1.08	1.44	1.67**
Stockton	0.98	1.16	1.20	0.68*	1.15	1.19
Ex-Stokesley+	0.44***	(0.10****)	0.55**	0.56	(0.78)	(0.26**)
Rest of Teesside (Base)	1.00	1.00	1.00	1.00	1.00	1.00
Hartlepool	0.66***	1.03	0.79	0.96	1.04	1.80****
Urban Districts	0.73**	0.64**	0.91	0.89	0.97	0.30***

+ Ex-Stokesley is that part of the area formerly Stokesley R.D. that is now in Cleveland County.

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F1.

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Table 8 presents relative risks (standardised for age) by "smoking group", a sub-division of the population by smoking habits into seven categories for males or five for females. If "current" is taken to mean the two years up to death for decedents or up to interview for the living, "other products" to mean one or more of pipe, cigar and hand-rolled cigarettes and "man. cigs" to mean manufactured cigarettes, we can define the categories as follows:

Never smoked	-	never smoked man. cigs or other products
Man. cigs only	-	current smoker of man. cigs who has never smoked other products
Mixed smokers	-	currently smokes one or both of man. cigs or other products and has smoked both at some time
Other smokers	-	current smoker of other products who has never smoked man. cigs
Ex-smokers	-	does not smoke currently but has previously smoked one or both of man. cigs or other products

All four diseases show a highly significant relationship with smoking manufactured cigarettes. This is most marked for lung cancer where a steep dose-response relationship is evident in both sexes, rates in each case being more than 15 times higher in the 23+ a day group than in the never smokers. The extent of the association for male lung cancer is similar to that found in the two major American prospective studies by Hammond (1966) and Kahn (1966), but perhaps somewhat less than that found by Doll and Peto (1976) in the British doctors study. (Their mortality rates were 78 per 100,000 for 1-14 a day smokers, 127 for 15-24 a day and 251 for 25+ a day as compared with 10 for non-smokers.) It is more difficult to compare our results for women validly as Hammond's figures, which indicate a weaker association, refer to a period when women had had a much shorter history of smoking, Kahn's figures relate only to men and Doll's figures published so far (he has not yet given 20 year follow-up figures for women) are based on very few deaths.

The dose-response relationship for chronic bronchitis is also clear, though rather less steep than that found in the prospective studies, especially by Doll and Peto (1976), where a mortality rate of 3 per 100,000 in non-smokers rose to 88 in the heaviest current smoking group.

TABLE 6

Relative risk of mortality (standardised for age) by smoking group

Smoking Category	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
Never smoked	1.00	1.00	1.00	1.00	1.00	1.00
Man. cigs only						
1-12 a day	4.58****	2.75****	1.97***	3.23****	3.14****	1.11
13-22 a day	6.24****	2.15****	1.88****	2.08***	7.78****	2.18***
23+ a day	15.10****	4.79****	2.55****	3.65****	16.68****	9.03****
Mixed smokers	5.29****	1.76**	2.48****	2.26***	-	-
Other smokers	3.32****	1.57*	1.51**	1.03	-	-
Ex-smokers	3.06****	2.05****	1.31	1.42	1.14	1.82**

For coronary heart disease and cerebrovascular disease, though there is a clear excess mortality of 1-12 a day smokers over never smokers, there is scarcely any dose-response as the relative risks for 23+ a day smokers are virtually the same as that of the 1-12 a day smokers. These findings are broadly similar to those of the prospective studies though the association we found with cerebrovascular disease is somewhat stronger than has appeared previously.

The risk of the group mixed smokers, all of whom have smoked manufactured cigarettes now or in the past, is intermediate between that of the manufactured cigarette only smokers and the never smokers for lung cancer and chronic bronchitis but of the same general order as that of the manufactured cigarette only smokers for the other two diseases. The risk of the other smokers group, who have never smoked manufactured cigarettes, is less for every disease than that for the mixed smokers but in each case except cerebrovascular disease it is greater than that of never smokers. The risk of ex-smokers is markedly less than that of continuing smokers for lung cancer, where it is not significantly greater than that of never smokers for women, and less than that of 1-12 a day smokers for men. The risk of ex-smokers is also less as regards coronary heart disease and cerebrovascular disease, where it is only slightly and non-significantly higher than that of never smokers. For chronic bronchitis, however, where many may have given up smoking because of the

[illegible] those of 15-22 a day smokers. In general all the findings described in this paragraph are, where comparisons can be made, not dissimilar from those found in the prospective studies.

Table 9 gives relative risks (standardised for age and the three levels of smoking) of manufactured cigarette only smokers by two other factors, level of inhalation and age of starting to smoke, found by other workers to have a marked relationship to risk of mortality from smoking-associated diseases. It must be borne in mind in considering the results for both of these factors that the reliability of answers given by the relatives of decedents must be open to doubt. The value of even self-reported inhaling habits has been questioned by some e.g. Doll and Peto (1976) and it is not unreasonable to assume that in many cases relatives of decedents might never have known the age at which the decedent started to smoke.

The results for inhaling show a clear trend for increasing mortality from both lung cancer and chronic bronchitis with increasing levels of inhalation, which is especially marked for women, some trend for cerebro-vascular disease and no significant trend at all for coronary heart disease. These results are somewhat at variance with those of Doll and Peto (1976) who found a clear association with inhalation for chronic bronchitis and coronary heart disease but no overall association for lung cancer, though there was an association at lower levels of smoking.

Our results for age of starting to smoke also disagree to some extent with those of other workers. While the general decreasing trend of death rates with increasing age of starting to smoke from age 15-19 up to age 25+ has been found before (e.g. Kahn (1966)), the finding of a lower risk in those starting before age 15 is not. This discrepancy might be at least partly explained by relatives tending to assume decedents had started to smoke at an average age of starting when they did not really know for certain. It is, of course, especially likely to be the case for those decedents who had started to smoke very early that the reporting relative did not have first-hand knowledge of age of starting to smoke.

TABLE 9

Relative risk of mortality (standardised for age and level of smoking) of manufactured cigarette only smokers by level of inhalation and by age at starting to smoke

Smoking Category	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
INHALING HABITS						
None	0.42***	0.57*	0.81	(0.24***)	0.29***	0.18****
Little	0.57**	0.62*	0.89	0.90	0.72	0.23***
Fair Amount	0.95	0.85	1.12	1.35	1.07	0.69
Lot	1.00	1.00	1.00	1.00	1.00	1.00
AGE OF STARTING TO SMOKE						
<15	0.44****	0.43****	0.63*	0.80	0.86	0.74
15-19	1.00	1.00	1.00	1.00	1.00	1.00
20-24	0.85	0.42***	1.07	0.36***	0.68	0.62
25+	0.54**	0.39***	0.97	0.75	0.57*	0.78

Note : Numbers of decedents and living by the levels of the factors studied in Tables 8 and 9 are given in Appendix F Table F2.

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a) Relative risk standardised for various characteristics

Table 10 gives the distribution of plain and filter smokers in the decedents and in the living population. As in all tables in this section, the analyses are confined to consideration of manufactured cigarette only smokers.

As we have established that amount smoked, level of inhalation and age at starting to smoke are all significantly associated with at least some of the causes of death studied, we look at the comparison of mortality rates of filter and plain smokers taking into account these smoking characteristics. Table 11 gives for each sex and cause of death the relative risk of mortality of filter cigarette smokers as compared with that of plain cigarette smokers. Four separate estimates of relative risk have been computed: standardised for age only; for age and amount smoked; for age, amount smoked and level of inhalation; and for age, amount smoked and age of starting to smoke. The categories used for amount smoked, level of inhalation and age of starting to smoke were those of Tables 8 and 9.

The results of Table 11 demonstrate two points clearly. Firstly, ignoring possible biasses to be considered later, there is statistically significantly smaller mortality associated with smoking filter cigarettes than with smoking plain cigarettes for all causes of death and both sexes regardless of which smoking characteristics are standardised for. Secondly, additional standardisation for smoking characteristics altered the estimates of relative risk by only a small amount, illustrating that these characteristics did not differ greatly between filter and plain smokers.

Having considered a number of smoking characteristics in comparing the mortality of filter and plain smokers, we next investigated the possibility that characteristics other than smoking habits of the average filter smoker may differ from those of the average plain smoker in a way relevant to mortality. We looked at each of the characteristics described in the study methods in turn to see whether or not filter smokers differed from plain smokers. The results which are given in detail in the supplementary tables available on request and which are summarised in Appendix F table F3, showed that there was no significant difference in either sex for tea drinking, amount of exercise taken, obesity index,

TABLE 10

Distribution of filter and plain smokers in the decedents and in the living population

		Male		Female	
		Filter	Plain	Filter	Plain
Decedents					
Lung Cancer	(Aged 35+)	118	214	71	30
Chronic Bronchitis	(Aged 35+)	91	147	45	25
Coronary Heart Disease	(Aged 35-64)	136	127	-	-
Cerebrovascular Disease	(Aged 35-64)	58	96	-	-
Living					
Aged 35+		810	312	988	170
Aged 35-64		538	241	-	-

TABLE 11

Relative risk of mortality (standardised for age, amount smoked and other smoking characteristics) of filter as compared with plain smokers

Relative risk standardised for	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis +
age only	0.41****	0.53****	0.60****	0.34****	0.55**	0.45***
age and amount smoked	0.42****	0.52****	0.60****	0.34****	0.53**	0.36****
age, amount smoked and inhalation	0.42****	0.55****	0.59***	0.36****	0.61**	0.36***
age, amount smoked and age of starting	0.41****	0.55****	0.66**	0.38****	0.43***	0.25****

+ The apparent fluctuations in relative risk for the female chronic bronchitis analyses are not significant as the numbers of deaths were small: see Appendix F.

[illegible] of females, death of relative from one of the four causes, or pollution level at home address. For males we found no difference in the frequency or type of alcohol consumed between filter and plain smokers, but we did find some differences for females, smokers of plain cigarettes drinking beer relatively more often and wine and spirits relatively less often than smokers of filter cigarettes. However, as no significant relationship was found in women between the type of alcohol consumption and either lung cancer or chronic bronchitis (see Appendix B) it did not seem worthwhile standardising the filter/plain relative risk estimates additionally for this characteristic.

For four characteristics we did find a significant difference between filter and plain smokers for both sexes. Plain smokers tended to be less likely to be in social class I or II, or drink coffee than filter smokers and more likely to be in social class V, have morning cough or have worked in a dusty job. However, as can be seen in Table 12, the estimates of relative risk of filter smoking as compared with plain smoking remained significant and relatively unchanged after standardising for age, smoking level and any one of these four characteristics. There still remains, of course, at least a theoretical possibility that there is some characteristic which we did not measure in which filter and plain smokers differed and which might have been responsible for the observed difference in mortality.

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TABLE 12

Relative risk of mortality (standardised for age, amount smoked and other non-smoking characteristics) of filter as compared with plain smokers

Relative risk standardised for	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
age and amount smoked	0.42****	0.52****	0.60****	0.34****	0.53**	0.36****
age, amount smoked and social class	0.40****	0.56***	0.58****	0.32****	0.53**	0.36***
age, amount smoked and coffee consumption	0.44****	0.55****	0.63***	0.38****	0.57**	0.44**
age, amount smoked and morning cough	0.44****	0.57***	0.62***	0.34****	0.60*	0.48**
age, amount smoked and dusty job	0.43****	0.51****	0.57****	0.34****	0.55**	0.36***

b) Effect of biasses on the relative risk estimates

As explained in section I.7, there are in theory two main potential sources of bias in our study method. The first of these is recall bias. Although we could not know for certain how different the answers to our questionnaire would have been had the decedents answered the questions themselves instead of having a near relative answer them, it was possible in two ways to gain some indication as to whether any marked bias had occurred.

Firstly, we compared the distribution of average answers collected from living people talking about themselves with that collected from living people talking about other people. Of the total living sample 47.7% of information on males and 62.1% of that on females was taken from the former category, i.e. "self-reported". We compared the distribution of "self-reported" and "other reported" answers for all the characteristics and the results are summarised in Appendix F table F4. Very few significant differences were found - in particular no difference was found for either sex in the proportions smoking filter and plain or smoking 1-12, 13-22 or 23+ cigarettes a day. The only characteristics for which significant differences were found in both sexes were that "self-reporting" tended to give a greater proportion of people who were mixed or ex-smokers, who had been exposed more often to fumes or who had worked in a dusty job. These differences all appeared to be related to events a long time ago which one would expect "self-reporting" to pick up more easily. In view of the general similarities between the two types of information, we concluded that it was valid to use, as we have done, all the data on the living population for estimating the filter/plain relative risk and not to recalculate these estimates excluding "self-reported" data.

Secondly, for lung cancer decedents only, we compared the distribution of smoking habits according to the person himself as taken from the hospital notes with that obtained from the relative in the subsequent interview. As illustrated in Appendix D there was a considerable area of agreement between the classifications by broad smoking habit from the two sources, within the limitations of the different groupings used due to the different types of questions asked. However the degree of correlation as regards amount smoked was not so good. This disagreement did not, however, consist of an obvious bias in any one direction, the overall distributions by amount smoked as measured

in the two different ways being fairly similar. No information was available on filter and plain smoking from the hospital notes but, as our findings did not suggest any consistent bias for type of smoker or amount smoked, there seemed no compelling reason why there should be one for filter/plain smoking, and we therefore decided not to try to make any correction for recall bias in our estimates.

Time bias, however, was quite a different proposition. It was already known that the ratio of filter to plain smokers nationally had increased sharply in the years preceding the study and it seemed likely that, had our information been obtained from the living population at the same average time as for the decedents, a smaller proportion of filter smokers would have been recorded. One way of correcting for this bias is to use the smoking history information that was recorded, go back to a fixed date, and compare the subsequent mortality of plain and filter smokers. This was done using 1969 as a convenient time point (ignoring information on cerebrovascular disease decedents before that point) and the results, given in Table 13, showed that for all causes of death the advantage to filter remained but was reduced and in some cases lost statistical significance.

It is noteworthy that most of the relative risks as compared with those given in Table 11 have increased by 20-30%, but for cerebrovascular disease the increase has been by 100%. This is not surprising because the Table 11 figure for cerebrovascular disease was based on deaths going back far longer (to 1966 - see Table 6) than for the other diseases, with consequently more time for the living to have switched from plain to filter.

TABLE 13

Relative risk of mortality of filter to plain smokers standardised for age and smoking level based on 1969 smoking information

Cause of death	Sex	Relative risk with 95% confidence limit
Lung Cancer	Male	0.54**** (0.40-0.73)
Chronic Bronchitis	Male	0.66** (0.47-0.94)
Coronary Heart Disease	Male	0.75* (0.55-1.02)
Cerebrovascular Disease	Male	0.68* (0.42-1.08)
Lung Cancer	Female	0.68 (0.42-1.11)
Chronic Bronchitis	Female	0.42*** (0.23-0.76)

As the relationship between coronary heart disease and smoking is very much stronger in younger age groups, filter/plain relative risks standardised for smoking level based on 1969 smoking information were also calculated for separate age groups for this cause of death. The values found (35-44 year olds = 0.34, 45-54 = 0.67, 55-64 = 0.94) are consistent with there being a larger difference between filter and plain in the age groups where the association with smoking is strongest.

The second way in which we tried to estimate the degree of time bias was by using the information on the number of plain and filter smokers supplied by Imperial Tobacco Limited for the years back to 1969. The distributions by year are given in the supplementary tables available on request and from these it was estimated that the degree of over-estimation of the lung cancer and chronic bronchitis relative risk was 1.30 for males and 1.41 for females, and that for coronary heart disease in males was 1.27. No direct estimate was available for cerebrovascular disease as the data did not go back far enough. However, assuming all the deaths to have occurred in 1969, the midpoint of the period covered 1966-72 yielded an estimate of bias of 2.00. Applying the estimate of bias to the relative risk estimates standardised for age and smoking level taken from Table 11, Table 14 gives estimates of the magnitude of relative risk very similar to those based on 1969 smoking habits.

TABLE 14

Relative risk of mortality of filter to plain smokers standardised for age and smoking level based on most recent smoking information and corrected for bias (see text)

Cause of death	Sex	Estimate of relative risk
Lung Cancer	Male	0.55
Chronic Bronchitis	Male	0.68
Coronary Heart Disease	Male	0.76
Cerebrovascular Disease	Male	0.68
Lung Cancer	Female	0.75
Chronic Bronchitis	Female	0.51

c) Mortality by time of switch from plain to filter

One aspect of the situation that we have not yet considered is whether there is any evidence that the longer people have smoked filter cigarettes the smaller their risk of dying from one of the four diseases becomes. We therefore considered smoking habits at three time points 1954, 1964 and 1969 dividing the population of current smokers, who had only smoked manufactured cigarettes, into those who had smoked plain cigarettes at all three time points, those who had smoked filter at all three, and those who had switched in between from plain to filter (Table 15). For comparability we included only those people who had kept the same smoking level (11-12, 13-22, or 23+) at all three points in time, and excluded the few switching from filter to plain. For every cause of death in both sexes the relative effect of filter smoking as compared with plain smoking is more marked the longer filter cigarettes had been smoked. For lung cancer in both sexes, coronary heart disease in males and chronic bronchitis in females the difference in risk between those smoking plain and those smoking filter at all three time points is highly significant and, though not significant at the 95% confidence level, the estimated difference in risk for chronic bronchitis and cerebrovascular disease in males is almost 2 to 1.

TABLE 15

Relative risk (number dead) of mortality of continuing plain smokers (base), continuing filter smokers and switchers from plain to filter based on smoking habits in 1954, 1964 and 1969

Cause of Death	Sex	Relative risk standardised for age and smoking level			
		Plain at all 3 time points	Plain 1954 Plain 1964 Filter 1969	Plain 1954 Filter 1964 Filter 1969	Filter at all 3 time points
Lung Cancer	Male	1.00 (194)	0.58** (30)	0.43**** (27)	0.39**** (21)
Chronic Bronchitis	Male	1.00 (112)	0.65 (19)	0.77 (23)	0.58* (18)
Coronary Heart Disease	Male	1.00 (121)	0.82 (37)	0.62** (33)	0.49*** (22)
Cerebrovascular Disease	Male	1.00 (45)	0.81 (13)	0.85 (15)	0.53 (8)
Lung Cancer	Female	1.00 (27)	1.37 (25)	0.59 (15)	0.34*** (14)
Chronic Bronchitis	Female	1.00 (23)	0.80 (13)	0.49 (12)	0.27*** (10)

d) Discussion

The results in Tables 13 and 15 indicate that filter smokers have a smaller risk of mortality than plain smokers for all the four causes of death. For lung cancer and chronic bronchitis for both sexes this difference is statistically significant when based either on 1969 smoking habits, or on a comparison of continuing (1954, 1964 and 1969) filter smokers with continuing plain smokers or both. The difference in risk of filter and plain smoking for coronary heart disease is not so large and is concentrated in the younger age-groups, but is still statistically significant when continuing filter and plain smokers are compared. The relative risk for cerebrovascular disease, which is based on rather smaller numbers of deaths, is not significant but again the trend markedly favours filter. For all causes of death the advantage of filter over plain increases the longer filter cigarettes have been smoked. Standardisation for inhalation, age of starting to smoke or any other measured characteristic not related to smoking had no serious effects on the value of filter/plain relative risk estimates.

Although we have investigated a number of factors related to the way people smoke, to try to see whether the difference could be attributed to the way the cigarettes are smoked rather than to the cigarette itself, we have not and could not have looked at all of them. For instance we did not study butt length as we doubted whether relatives of decedents could accurately assess this. Todd et al (1976) have published figures demonstrating that in the United Kingdom, the average weight of tobacco smoked per filter cigarette was no less than the average weight per plain cigarette over the last 20 years, being indeed somewhat greater up to about 1968. It seems unlikely, therefore, that taking butt length into account would have affected markedly our estimate of filter/plain relative risk.

Although our study appears to show a clear difference in the mortality of filter and plain smokers, one must bear in mind the way in which information about smoking habits was collected with the inherent possibilities both of recall and time bias. We investigated recall bias in two ways. Firstly, we showed that the distribution of "self-reported" answers for the living population matched quite closely that of "other-reported" answers. Secondly, in the lung cancer decedents, we found differences, but no systematic ones, between the smoking habits as

reported by the person himself and those given by the relative. A comparison of information as to cigarette smoking status obtained both from personal and next-of-kin questionnaires has also been made by Rogot and Reid (1975). Their findings, which were rather similar to ours, showed that of 664 people reported by themselves to smoke, 77 were classed as non-smokers or occasional smokers by their next-of-kin. This can help to explain why the relative risks of smokers to non-smokers in our Table 8 are very much less than those found in prospective studies such as Kahn (1966), Hammond (1966) or Doll and Peto (1976). For example, we found 25 males with lung cancer who were reported never to have smoked as compared with 591 who apparently had done. Had this 25 contained 12 mis-reported by their relatives, i.e. only 2% of the "true" total smokers, mortality ratios of any group as compared with non-smokers would have been under-estimated by a factor of about 2.

However, random errors in classification of smoking habits could not explain why the filter/plain relative risks we have observed are so large, as in general random errors tend to reduce rather than increase associations. For the true difference between the effects on mortality of filter and plain smoking to have been smaller than we have found there would have had to have been a systematic over-representation of the proportion of filter smokers in the living or an under-representation in the decedents (or both) and there is no obvious reason why this should have happened. Thus it seems doubtful that recall bias could explain away any substantial part of the large filter/plain differences found.

Nor do we think it likely that our corrections for time bias were seriously inaccurate as the estimates of relative risk obtained in two ways in Tables 13 and 14 are so similar. Nevertheless, in view of the theoretical possibility of biasses of this type, it seems advisable to treat our results as suggestive until confirmed.

All other published evidence on the relative risk of lung cancer mortality related to smoking filter and plain cigarettes has come from the U.S.A. Notwithstanding our reasons for caution in interpreting our results, and the fact that there are differences between the U.K. and the U.S.A., both in the time at which filters made a serious impact on the market and in the type of filters commonly used, it is interesting to note that the relative risk of lung cancer for males found in our study

(0.54 to 1) is very similar to that found by both Bross and Gibson (1968) (0.60 to 1) and by Wynder et al (1970) (0.62 to 1). Consideration of the results in Table 1 which show a ratio of tar yields of filter to plain cigarettes on average of about 0.7 to 1 in the U.K. over the period 1967 to 1975, and of those given by Wynder et al (1970), who showed a ratio of about 0.8 to 1 in the U.S.A. over the period 1958 to 1969, suggest that this difference in risk is greater than is the difference in tar yields.

In the three large prospective studies mentioned in section I.9 an approximately linear relationship was found between lung cancer incidence rate and number of cigarettes smoked per day. Assuming both that total daily tar intake is approximately proportional to the number of cigarettes smoked, and that lung cancer risk is related to tar intake, it might have been expected that the filter/plain differential in risk observed in our study would not have been greater than the ratio of tar yields. Indeed, since most filter smokers have smoked filter cigarettes for only part of their lives, one might have expected the differential in risk to be less marked than the differential in tar yields. However, there are two reasons which might explain our apparently contradictory results. Firstly, extrapolation from a situation in which, effectively, the dose of tar per "application" was constant and the frequency of application varied, to our situation, in which the dose varied but the frequency was constant, is not necessarily sound. It does not follow that the reduction in risk as compared with smoking 20 cigarettes of a given tar is the same for the situation when 10 cigarettes of the same tar are smoked as for the situation when 20 cigarettes of half the tar are smoked. Secondly, studies on mice (Davies et al (1974)) have shown that, if equal numbers of applications of cigarette smoke condensate are given per week, the tumour incidence rate is proportional more nearly to the square of the amount of tar applied per dose than to the amount of tar itself. Our results would also appear to fit a square law hypothesis very approximately.

However, before it be thought proven that the reduction in risk associated with a reduction in tar is as dramatic as our study indicates, it should be pointed out that two studies published more recently have indicated a much smaller reduction in risk. Firstly, Wynder et al (1975) presented results in graphical form showing the relative risk of lung cancer for current filter and non-filter smokers separately for smokers of 1-10, 11-20, 21-40 and 41+ cigarettes per day based on a hospital

case-control study carried out in men in three cities in the U.S.A. The average relative risk appeared to be somewhere between 0.80 and 0.85, i.e. somewhat similar to the tar reduction. Secondly, Hammond et al (1976), using data from his million person study, divided the population of smokers into high, medium and low T/N (tar/nicotine) groups and compared their mortality prospectively. The ratio they found for females of the mortality of the low T/N to high T/N groups was about 0.60 but that for males was nearer 0.80. Thus, although there is general agreement that the switch to filters, whether considered directly or through the concomitant switch to lower tar cigarettes, has been associated with reduced lung cancer mortality, there is some doubt as to the true extent of this reduction.

We also found a marked reduction in coronary heart disease mortality associated with smoking filters. This was in the opposite direction to the association suggested by Wald (1976). He thought that, because of their currently higher average carbon monoxide levels, filter cigarettes might produce a higher risk than plain cigarettes since animal experiments by Astrup (1972) had indicated that carbon monoxide may be a major contributor to heart disease. Wald went on to postulate that part of the observed rise in heart disease mortality in the U.K. may have been due to the switch to filters. However, according to Bentley (1976), it is likely that this excess carbon monoxide of filter brands was only of recent origin, being due to a greater reduction of CO yields from plain brands around 1973 resulting from the use of very high porosity paper. Before then there was probably little difference between the two types of cigarette in carbon monoxide yield, though for both of them the general trend was downward. In any case Wald's hypothesis does not seem consistent with findings from the United States. There coronary disease mortality is falling (Metropolitan Life, 1975), with the majority of smokers having switched to filters earlier than in the U.K. (Wootten, 1960).

Our finding was consistent in direction; but not in magnitude with that found by Hammond et al (1976), who found an average heart disease mortality ratio of only 0.86 of low T/N smokers as compared with high T/N smokers. No other workers have published results on chronic bronchitis and cerebrovascular disease and until they do the true magnitude of the relative associations of filter and plain smoking must remain in doubt.

In view of the importance of this subject, it will be of interest to see what results emerge from the large hospital case-control study of the same four diseases to be carried out by Professor M.R. Alderson in 10 areas of the U.K. In the meantime, it seems reasonable to read our results as strongly suggestive that the general switch to filter cigarettes has been beneficial.

1.11 Summary of main findings

Mortality from all four diseases studied was significantly associated both with increasing age and with the smoking of manufactured cigarettes. The association with cigarettes was strongest for lung cancer and chronic bronchitis where there was a clear trend both with the number of cigarettes smoked and with the level of inhalation. It was weaker for coronary heart disease and cerebrovascular disease where neither a significant dose-response relationship nor a significant effect of inhalation was seen.

The smoking of filter cigarettes was less associated with mortality from all four diseases than was the smoking of plain cigarettes. This advantage of filter cigarettes, which was statistically significant for all the diseases except cerebrovascular disease, increased the longer filter cigarettes had been smoked. Those who had smoked filter cigarettes since 1954 had an estimated risk of mortality from each of the four diseases which was about a half that of continuing plain smokers. Although this estimate has been corrected for the fact that the information on the living and the decedent populations related to different points in time, further study is still needed in view of the possibility of other biassing factors that are discussed.

Appendix A - Mortality by other aspects of the smoking habit

In Section I.9 we looked at the mortality associated with some principal features of the smoking habit, and in particular with those features which might potentially have biassed the filter/plain comparison. In this section we look briefly at the data we collected on other aspects of the smoking habit.

Table A1 presents relative risks of mortality (standardised for age) of a more detailed breakdown of the population by smoking group than that given in Table 8. For lung cancer in males it can be seen that all the large relative risks are related to smoking cigarettes in some form or at some time, though there is no significant excess risk in cigarette smokers when they have given up for 19 years or more. Smokers of hand-rolled cigarettes appear to have a risk of lung cancer approximately intermediate between that of smokers of plain and filter cigarettes. Smokers of pipes have a smaller risk, but one still about twice that of never-smokers. This ratio is similar to that given by both Kahn (1966) and Hammond (1966). There were too few smokers of cigars for useful conclusions to be made.

For the other causes of death the relative risk also appeared to be mainly related to the smoking of cigarettes, though the relative risks related to pipe-only smoking were all about 1.75 to 1. Kahn (1966) found a similar excess in pipe smokers for bronchitis but not for coronary heart disease or cerebrovascular disease. The finding of a significant excess risk of chronic bronchitis which persisted long after giving up smoking, but no significant excess heart disease or cerebrovascular disease in ex-smokers, was similar to that found by Doll and Peto (1976).

Table A2 looks at mortality by type of manufactured cigarette smoked. Within the plain and filter categories relative risks (standardised for age and amount smoked) are given by standard cigarette classifications based mainly on size. The results for plain cigarettes showed no overall advantage for either of the two categories considered though there was some indication that chronic bronchitis mortality might have been greater in smokers of small plain cigarettes than in smokers of medium or large ones. The results for filter cigarettes did not show any consistent advantage for any of the three categories studied. The apparent advantage of king-size smokers was not statistically significant for the majority of the causes of death studied, the relative risks being based on

Tob Res Counc Res Rep 14 (part 1) 1977

TABLE A1

Relative risk of mortality (standardised for age)
by detailed smoking group

Detailed Smoking Group Category	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
Never smoked (base)	1.00	1.00	1.00	1.00	1.00	1.00
Man. cig. only smokers-filter cigarettes	4.74****	2.05****	1.71***	1.67**	4.88****	1.65**
Man. cig. only smokers-plain cigarettes	11.08****	3.72****	2.83****	4.93****	9.23****	3.36****
Hand-rolled only	6.91****	1.49	1.41	0.84	-	-
Pipe only	2.15**	1.80**	1.74*	1.72	-	-
Cigars only	(0.00)	(0.89)	(0.57)	(0.00*)	-	-
Mixed "others"+ only	(2.44)	(0.56)	1.62	(0.55)	-	-
Man. cigs. and "others" now	5.91****	1.33	2.22****	1.75*	-	-
Man. cigs. now, "others" once	6.55****	4.23***	4.03***	7.65****	-	-
Hand-rolled now, man. cigs. once	8.62****	4.31****	4.26****	4.16***	-	-
Pipe now, man. cigs. once	4.35***	1.52	1.96	(3.20*)	-	-
Cigar now, man. cigs. once	(0.71)	(0.00**)	(1.10)	(0.00*)	-	-
Mixed "others" now, man. cigs. once	10.06****	1.00	3.67**	(1.21)	-	-
Ex-smokers of man. cigs. only						
Gave up ≤4 years ago	4.87****	2.27***	1.00	1.67	(1.63)	1.26
Gave up 5-8 years ago	4.16***	2.52**	1.84	(2.26)	(1.09)	2.64*
Gave up 9-18 years ago	2.99***	2.09**	1.17	1.73	(0.72)	1.99**
Gave up 19+ years ago	1.31	1.58	1.09	(0.88)		
Total	3.21****	2.07****	1.17	1.55	1.14	1.82**
Other ex-smokers	2.94****	1.98**	1.65*	1.14	-	-

Note: Numbers of decedents and living by the levels of these factors are given in Appendix F Table F5.

+ "Others" contains hand-rolled, pipe and cigars.

[illegible] small numbers of deaths. In any case, one must bear in mind the possibility that relatives may have had difficulty classifying decedents very exactly by type of cigarette smoked. It is interesting nevertheless that, as with smokers of plain cigarettes, smokers of small cigarettes have somewhat higher bronchitis mortality than smokers of medium cigarettes. Combining the results for plain and filter cigarettes and for both sexes, this difference is highly significant.

Table A3 gives the relative risk of mortality (standardised for age) by a detailed breakdown of the number of manufactured cigarettes smoked. In view of the smaller numbers of people at each level the trends in risk for lung cancer and bronchitis mortality are not so smooth as those seen in Table 8. However the complete lack of dose response for coronary heart disease and for cerebrovascular disease noted in section I.9 is emphasised. The large relative risks for female 48+ a day smokers have very wide confidence limits, since only three women in the living population were found who smoked as much as this.

In view of Doll and Peto's (1976) finding that the relationship between inhaling level and mortality from lung cancer depended on the amount smoked, we investigated this in Table A4. Our results, which are presented for all the other causes of death as well, did not give any indication that the association with inhaling varied by amount smoked. Although the numbers of deaths on which each figure is based are fairly small (see Table F5) they would have been sufficient to pick up the very marked reversal noted by Doll and Peto who found the relative risk of lung cancer of inhalers compared with non-inhalers to be about 2 to 1 for smokers of 1-14 cigarettes a day, but less than 0.5 to 1 for smokers of more than 25 a day.

Table A5 similarly investigates whether the association found between age of starting to smoke and mortality depended on the amount smoked. The results did not indicate any reason why the association found for all smokers did not apply at each level of smoking. In considering the results of Table A4 and Table A5 the limitations of information from relatives on the subject of inhalation and age of starting to smoke which were mentioned in section I.9 should be borne in mind.

TABLE A2

Relative risk of mortality (standardised for age)
by type of manufactured cigarette smoked

Type of manufactured cigarette smoked	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
Never smoked (base)	1.00	1.00	1.00	1.00	1.00	1.00
Plain cigarettes						
Small	10.30****	4.65****	2.50****	4.42****	7.38****	4.10****
Medium/Large	10.19****	3.33****	3.25****	4.67****	9.29****	2.86**
Filter cigarettes						
Mini/Small	3.47****	2.57***	2.25***	(0.87)	4.52****	1.78*
Intermediate/Medium	4.35****	1.94***	1.78***	1.80**	5.70****	1.56*
King-size	2.55*	1.98	0.83	1.28	(1.51)	(1.18)

TABLE A3

Relative risk of mortality (standardised for age)
by number of manufactured cigarettes currently smoked

Number of manufactured cigarettes smoked	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
Never smoked (base)	1.00	1.00	1.00	1.00	1.00	1.00
1-7	3.35****	3.10****	2.47***	2.55**	2.85***	0.84
8-12	4.37****	2.74****	1.82**	3.24****	3.39****	1.32
13-17	5.42****	1.39	2.24***	2.57***	7.18****	1.84
18-22	5.88****	2.58****	1.79***	1.74**	7.19****	2.39***
23-27	12.75****	6.33****	2.50***	2.24	(2.25)	5.07*
28-32	12.22****	4.31****	2.70***	4.11****	11.36****	6.55****
33-47	13.33****	3.54****	2.70****	4.07****	23.25****	17.68****
48+	28.46****	10.31****	2.48**	(2.65)	167.97****	341.82****

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F5.

In Table 8 we looked at the relative risks of mortality associated with belonging to one of seven groups based mainly on "current" smoking habits, where current related to the 2-year period before death or interview. As these periods related to somewhat different points in time, and as we wanted also to gain some information on the relative contributions of current and past smoking to the association, we decided to look additionally at the relative risks of mortality by the same seven groups, but based on smoking habits as at particular years. The results for three particular years 1969, 1964 and 1954 are given in Table A6. In general the pattern of relative risks is very similar to that given in Table 8. This is not surprising in view of the fact that the smoking habits of many of the population remain constant over a long period of time. The only significant trend of relative risk with time is for lung cancer in males, especially ex-smokers. This finding is also to be expected in view of the result in Table A1 that the risk of lung cancer reduces with the number of years for which smoking has been given up.

TABLE A4

Relative risk of mortality (standardised for age)
by inhaling and by number of manufactured cigarettes smoked

Number of cigarettes smoked/inhaling level	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
1-12 a day						
None	0.66	0.63	0.57	(0.43)	(0.25)	0.30*
Little	0.68	0.88	1.07	1.46	1.15	0.30*
Fair amount	0.54	1.01	0.85	1.03	3.08	(0.35)
Lot (base)	1.00	1.00	1.00	1.00	(1.00)	(1.00)
13-22 a day						
None	(0.18***)	(0.44)	(0.71)	(0.00**)	0.42	(0.14**)
Little	0.36**	0.47	0.85	(0.35*)	0.40*	(0.13**)
Fair amount	1.08	0.80	1.34	1.02	0.78	0.50
Lot (base)	1.00	1.00	1.00	1.00	1.00	1.00
23+ a day						
None	(0.43)	(0.70)	(1.80)	(0.00)	(0.12*)	(0.05**)
Little	0.77	(0.37)	0.76	(1.27)	(1.44)	(0.00**)
Fair amount	1.12	0.77	0.96	2.22**	0.92	1.55
Lot (base)	1.00	1.00	1.00	1.00	1.00	1.00
All man. cig. smokers	(standardised for age and amount smoked)					
None	0.42***	0.57*	0.81	(0.24***)	0.29***	0.18****
Little	0.57**	0.62*	0.89	0.90	0.72	0.23***
Fair amount	0.95	0.85	1.12	1.35	1.07	0.69
Lot (base)	1.00	1.00	1.00	1.00	1.00	1.00

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F5.

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TABLE A5

Relative risk of mortality (standardised for age)
by age of starting to smoke and by number of manufactured cigarettes smoked

Number of cigarettes smoked/age of starting to smoke	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
1-12 a day						
<15	0.67	0.28***	(0.33*)	(0.60)	(0.41)	(0.00)
15-19 (base)	1.00	1.00	1.00	1.00	1.00	1.00
20-24	0.80	0.31***	0.62	0.45	(0.54)	(0.00**)
25+	0.55	0.50	0.54	(0.46)	0.51	0.87
13-22 a day						
<15	0.40***	0.59	0.72	(0.75)	(0.88)	(0.00)
15-19 (base)	1.00	1.00	1.00	1.00	1.00	1.00
20-24	0.88	0.68	1.13	(0.12***)	0.85	(0.93)
25+	0.67	0.34	1.20	(0.93)	0.53	0.94
23+ a day						
<15	0.37***	0.46*	0.71	0.93	(2.14)	(2.21)
15-19 (base)	1.00	1.00	1.00	1.00	1.00	1.00
20-24	0.89	0.27*	1.51	(0.52)	1.05	(1.03)
25+	0.34*	0.22*	1.64	(1.38)	0.89	(0.40)
All man. cig. smokers	(standardised for age and amount smoked)					
<15	0.44****	0.43****	0.63*	0.80	0.86	(0.74)
15-19 (base)	1.00	1.00	1.00	1.00	1.00	1.00
20-24	0.85	0.42***	1.07	0.36***	0.68	0.82
25+	0.54**	0.39***	0.97	0.75	0.57*	0.78

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F5.

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TABLE A6

Relative risk of mortality (standardised for age)
by smoking habits as at 1969, 1964 and 1954

Previous smoking habits	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis	Lung Cancer	Chronic Bronchitis
As in 1969						
Never smoked (base)	1.00	1.00	1.00	1.00	1.00	1.00
Man. cigs. only 1-12 a day	4.35****	3.08****	1.89***	2.51***	2.86****	0.90
13-22 a day	5.69****	1.89***	1.79****	1.60	6.73****	2.31****
23+ a day	11.99****	3.94****	2.44****	2.99****	15.38****	7.15****
"Mixed" smokers	5.47****	1.32	2.32****	2.53***	-	-
"Other" smokers	4.06****	1.77***	1.85****	1.45	-	-
Ex-smokers	3.05****	2.24****	1.32	1.36	(0.78)	2.30***
As in 1964						
Never smoked (base)	1.00	1.00	1.00	1.00	1.00	1.00
Man. cigs. only 1-12 a day	3.91****	2.39****	1.54**	2.32***	2.70****	0.87
13-22 a day	5.68****	1.98***	1.87****	1.58*	6.51****	2.87****
23+ a day	12.21****	4.77****	2.50****	3.41****	15.89****	6.69****
"Mixed" smokers	4.53****	1.40	2.45****	2.50***	-	-
"Other" smokers	4.20****	1.90***	1.67***	1.68*	-	-
Ex-smokers	1.86**	1.82**	1.13	1.57	(0.91)	2.14**
As in 1954						
Never smoked (base)	1.00	1.00	1.00	1.00	1.00	1.00
Man. cigs. only 1-12 a day	3.44****	2.08****	1.38	2.22***	3.15****	1.00
13-22 a day	5.44****	1.91***	2.01****	2.02***	6.41****	2.89****
23+ a day	10.46****	4.65****	2.45****	3.59****	15.09****	6.01****
"Mixed" smokers	4.53****	1.78**	2.35****	2.73****	-	-
"Other" smokers	3.36****	1.72**	1.64***	1.10	-	-
Ex-smokers	1.69*	1.54	1.17	0.99	(0.99)	2.13**

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F5.

Appendix B - Mortality by some personal and environmental factors

In this section we look briefly at the apparent relationship each of those other personal and environmental factors which we studied have to mortality from the four causes of death. To illustrate this, the relative risks of mortality, standardised for age and smoking group, related to each of the factors are presented in Tables B1 to B4. In attempting to interpret the findings it is important to bear in mind that, unlike filter/plain smoking habits, we do not have available any independent evidence on the nature and extent of any time or recall biasses that may exist. The reader is therefore advised to treat any of the findings in this Appendix as indicating no more than the possibility of real relationships which only further research can confirm or refute.

Coffee drinking (Table B1)

The living and decedent populations were classified simply as drinkers of no coffee, of 1-5 cups a day or of 6 cups or more a day. Those who drank no coffee had higher risks of mortality from each one of the diseases studied than those who drank 1-5 cups a day, this difference being highly significant in all cases except for lung cancer in females. Drinkers of 6 or more cups a day were relatively rare, and results therefore more uncertain, but in general they fitted in with the trend of decreasing mortality with increasing coffee consumption.

As coffee drinkers tend to differ from non-coffee drinkers in many respects, we looked to see whether any of the other factors which we have measured might account for our observed association. Standardisation, in addition to that for age and smoking group, for either social class (coffee drinkers tended to be of higher social class than non-coffee drinkers) or filter/plain smoking (coffee drinkers smoke relatively more filter cigarettes) scarcely altered the relative risk estimates. Nor did it seem likely that any other factor we had studied could have more than marginally biassed the relative risk estimates, since there was no other factor which was strongly associated both with coffee drinking and mortality. Time bias could explain a small part of the relative risk as coffee consumption tended to increase in the years up to 1972, but this would still leave the major part of the apparent association unexplained.

TABLE B1

Relative risk of mortality (standardised for age and smoking group) by coffee and tea consumption, by alcohol frequency and sort of drink usually taken

Factor studied/ Level of factor	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
COFFEE (cups per day)						
None	2.07****	2.78****	1.61****	1.98****	1.38*	2.30****
1-5 (base)	1.00	1.00	1.00	1.00	1.00	1.00
6+	1.00	(1.02)	0.55*	(0.35**)	(0.64)	(0.67)
TEA (cups per day)						
None	0.47*	(0.48)	(0.34**)	0.66	(0.00**)	(0.00**)
1-5 (base)	1.00	1.00	1.00	1.00	1.00	1.00
6+	1.22*	1.43***	1.35****	1.17	1.65***	1.64***
ALCOHOL FREQUENCY						
Most days/2-3 times a week	1.76****	1.30*	1.01	1.26	1.34	1.25
Once a week/once a month (base)	1.00	1.00	1.00	1.00	1.00	1.00
Less often/not at all	1.31*	1.00	1.25	1.21	1.28	1.02
DRINK USUALLY TAKEN						
Beer	1.47***	1.42***	1.03	0.99	1.26	1.65***
Not beer or non-drinker (base)	1.00	1.00	1.00	1.00	1.00	1.00
Spirits	0.98	1.23	1.00	1.33	0.95	1.13
Not spirits or non-drinker (base)	1.00	1.00	1.00	1.00	1.00	1.00
Wine	0.45***	0.35****	0.47***	0.86	1.40	1.05
Not wine or non-drinker (base)	1.00	1.00	1.00	1.00	1.00	1.00

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F6.

Our findings for coronary heart disease are at variance with those from other workers (e.g. Yudkin et al (1964), Jick et al (1972), Hennekens et al (1976)) which have shown either no effect or some adverse effect of coffee. As far as we are aware there is no other available epidemiological evidence on coffee drinking as regards the other diseases. Further study seems indicated.

Tea drinking (Table B1)

Questions about tea drinking were asked similarly to those on coffee drinking. In this case, however, mortality trends were in the opposite direction, drinkers of 6 or more cups a day having risks significantly higher than those of 1-5 cups a day for all causes studied except cerebrovascular disease. Only 3% of the living population drank no tea, but even so their relative risks could be shown to be significantly low for a number of the diseases.

In previous published work, no clear connection between tea drinking and mortality was found for lung cancer in men (Stocks, 1957), nor for acute myocardial infarction (Jick and Slone, 1972).

Alcohol consumption (Table B1)

Questions were asked both on frequency of consumption of alcohol (on a six point scale) and on the type of drink usually taken. After standardising for age and smoking only one significant difference was found between those who drank most days or 2-3 times a week and those who drank once a week or once a month. This was for lung cancer in males where the relative risk for the more frequent drinkers of 1.76 was highly statistically significant. Additional standardisation for social class tended to increase slightly the relative risk estimates for this comparison for lung cancer and bronchitis, the bronchitis comparison for males becoming significant at the 95% confidence level (relative risk 1.46). No significant differences were found for heart disease or stroke, whether standardised additionally for social class or not. Nor was any significant difference found when those who drank less often that once a month or not at all were compared with the intermediate group of drinkers.

Those who drank beer had an excess mortality from lung cancer and bronchitis as compared with those who did not, this excess being marked when social class was standardised for. On the other hand, those who

TABLE B2

Relative risk of mortality (standardised for age and smoking group) by lack of exercise, obesity index, presence of morning cough and whether close relative had died of related diseases

	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
LEVEL OF EXERCISE						
A lot	1.56****	1.27	1.15	0.82	1.64**	1.75***
Moderate (base)	1.00	1.00	1.00	1.00	1.00	1.00
Little or none	0.87	1.71****	1.47***	1.15	0.58**	1.66***
OBESITY INDEX						
>3.6	0.70***	0.60****	1.18	1.19	1.43	1.39
3.2 - 3.6 (base)	1.00	1.00	1.00	1.00	1.00	1.00
<3.2	1.17	1.28*	0.98	0.87	1.68**	2.01****
MORNING COUGH						
Usually coughs first thing a.m.; in winter and summer	2.79****	8.02****	1.38***	1.22	4.76****	5.84****
Does not (base)	1.00	1.00	1.00	1.00	1.00	1.00
DEATH OF RELATIVE						
Close relative died of bronchitis, cancer, heart attack or stroke	1.61****	1.70****	2.14****	2.49****	1.70***	1.53***
Did not (base)	1.00	1.00	1.00	1.00	1.00	1.00

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F6.

drank spirits had similar mortality to those who did not, while those who drank wine tended to have a reduced mortality, this reduction being significant for three diseases in males.

Stocks (1957) found an association between lung cancer and beer drinking in light cigarette smokers, pipe smokers and non-smokers but no association in men smoking over 100 cigarettes weekly. On the other hand, Schwartz et al (1957) concluded that, after taking into account tobacco consumption, alcohol was not associated with cancer of the lung and Sackett et al (1968) in an autopsy study found no relation between the degree of aortic atherosclerosis and the use of alcohol.

Level of exercise (Table B2)

Our findings show for both sexes a positive relationship between amount of exercise taken and lung cancer mortality, those who took a lot of exercise having about twice the risk of those who took little or no exercise. For coronary heart disease, on the other hand, the trend was significantly negative with those who took little or no exercise having high risks. The relationship with chronic bronchitis mortality was U-shaped, especially for women, where both extremes of the scale had significantly higher risks than the moderate exercisers.

Obesity index (Table B2)

Obesity index was not significantly related to either coronary heart disease or cerebrovascular disease, but it was related to lung cancer and bronchitis to some extent, fat men having significantly smaller risks and thin women having significantly larger ones.

Morning cough (Table B2)

Morning cough was found, as expected, to have a very strong positive relationship with chronic bronchitis mortality. This relationship was also strong for lung cancer, but much weaker (though still significant) for coronary heart disease.

Death of relative (Tables B2 and B3)

For all diseases, there was a greater tendency for the decedents rather than the living to have had at least one close relative reported to have died from bronchitis, cancer, heart attack or stroke. This was

TABLE B3

Relative risk+ of mortality (standardised for age and smoking group) by whether parent or sibling died of bronchitis, lung cancer, heart attack, stroke or other cancer

	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis
PARENT DIED OF						
Lung Cancer	1.80*	(0.53)	(0.34**)	(0.45)	(0.34)	(0.86)
Bronchitis	0.95	1.74**	0.67*	1.01	(0.00****)	1.53
Heart Attack	1.20	1.02	2.68****	1.70**	1.20	0.98
Stroke	1.00	1.21	1.17	3.08****	(0.57)	(0.37**)
Other Cancer	1.58***	0.96	1.14	1.01	1.91**	0.96
SIBLING DIED OF						
Lung Cancer	3.16****	1.11	0.88	1.38	2.21*	0.89
Bronchitis	2.49**	6.55****	1.29	2.98*	3.54**	4.98****
Heart Attack	1.73**	2.90****	6.07****	5.08****	1.50	2.66****
Stroke	2.08*	2.68***	2.41**	8.49****	3.12**	3.29***
Other Cancer	1.70***	1.62**	1.53*	2.81****	2.62****	0.89

+ Relative risks quoted are compared with those who did not have a parent (or sibling) who had died of the particular disease

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F6.

somewhat more marked for decedents from coronary heart disease or cerebrovascular disease than for lung cancer or bronchitis (Table B2).

In Table B3 this analysis is broken down by considering whether the relative was a parent or a sibling of the deceased, and which particular disease was involved. Three significant findings are clearly seen from the results. Firstly, having had a sibling reported as having died from one of the diseases was far more predictive of mortality from any of the diseases studied than having had a parent so reported. Secondly, decedents from one particular disease were very much more likely than the living controls to have had a relative reported as dying from the same disease. Thirdly, decedents from one particular disease were usually more likely, and often significantly more likely, than living controls to have had a relative reported as dying from another one of the diseases. The second conclusion is seen most clearly in Table B3 by noting the large relative risks in the descending diagonals, while the third conclusion stems from the tendency of off diagonal relative risks to exceed the value of 1 that would be expected had no association been present.

In considering these results the strong possibility of recall bias must be borne in mind. In particular it seems quite plausible that the relative of the decedent is more likely to remember a case of another person in the family dying from the same cause that the decedent died of rather than from some other cause.

Exposure to dust, fumes and pollution (Table B4)

No marked association was found between general exposure to dust, gas or fumes at work and mortality from any of the disease studied, though men working in dusty jobs did have a small but significant excess (28%) mortality from chronic bronchitis.

When particular types of dusty job were studied, this excess bronchitis rate was clearest in foundry workers. A significant association, though based on very small numbers of deaths, between working with asbestos and mortality from both lung cancer and coronary heart disease was also found.

More marked than the association of mortality with exposure to dust or fumes at work was that with exposure to pollution in area of residence. Those living in areas of high pollution had about 70% greater mortality, for all the diseases studied, than those living in areas of intermediate pollution.

TABLE B4

Relative risk of mortality (standardised for age and smoking group) by exposure to dust, fumes or pollution

	Male				Female	
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis	Lung Cancer	Chronic Bronchitis
EXPOSURE TO FUMES						
Ever exposed to gas or fumes	1.16	1.07	1.05	0.92	1.79	1.08
Not exposed (base)	1.00	1.00	1.00	1.00	1.00	1.00
EXPOSURE TO DUST						
Ever worked in a dusty job	1.04	1.28**	0.99	0.89	1.07	1.18
Never worked (base)	1.00	1.00	1.00	1.00	1.00	1.00
TYPES OF DUSTY JOB+						
Coalmine	0.73	1.31	1.42	0.81	-	-
Other mine	0.83	1.15	1.30	0.72	-	-
Foundry	1.01	1.68***	1.09	1.23	-	-
Asbestos	3.48**	(0.55)	3.02**	(0.00)	-	-
Other dusty job	1.22**	1.20*	0.96	0.95	-	-
POLLUTION LEVEL AT HOME ADDRESS⊖						
High	1.69****	1.76****	1.74****	1.80***	1.57*	1.67**
Intermediate (base)	1.00	1.00	1.00	1.00	1.00	1.00
Low	1.30*	0.79	1.25	1.45*	1.47	0.95

+ For each of the 5 types of dusty job, relative risks quoted are compared with the total population excluding that 1 type and are standardised for age only.

⊖ Estimates available for Teesside C.B. only

Note : Numbers of decedents and living by the levels of these factors are given in Appendix F Table F6.

Appendix C - Distribution of type of lung cancer found

Two years after the interviewing in the main study had been completed, it was felt that it might be useful if information could be obtained on the lung cancer type of the decedents from lung cancer. It has been pointed out by a number of other workers that the association between smoking and lung cancer was mainly present in those dying from squamous or oat-cell carcinoma and that there was little or no association between smoking and adenocarcinoma. We felt that by removing the adenocarcinoma cases from the decedents we might clarify some of the relationships between aspects of the smoking habit and lung cancer.

By reference to histological and cytological information from the hospital records we were able to classify the majority of the lung cancer decedents (i.e. those who had lung cancer on their death certificates) by the type of lung cancer they had. Table C1 summarises the information found. It can be seen that the percentage of lung cancer decedents definitely known to have had adenocarcinoma was very small, 3.4% of males and 6.2% of female cases. This percentage is similar to that given by Doll and Hill (1954) who found 33 adenocarcinomas in their series of 916 lung cancers but less than that found by some other workers, e.g. Ashley and Davies (1967). As Whitwell et al (1974), who studied cases occurring in Broadgreen Hospital, Liverpool, showed, the frequency of adenocarcinoma can depend very much on how the lung cancer cases are obtained. They found 2% in a bronchial biopsy series, 9.5% in an operation specimen series and 28% in a postmortem series.

We next looked at the relationship between lung cancer type and smoking habits. Table C2 gives for each of the main groups of lung cancer type, the distribution of smoking habits as given by the person himself which had been extracted from the hospital records. For males, although there was a somewhat greater proportion of non-smokers among the adenocarcinoma group than among the other groups, this difference did not approach significance in view of the small numbers involved. For females there was only one person who both had an adenocarcinoma and had smoking habits available, and although she was a non-smoker no conclusions could validly be drawn. For both sexes the distribution of smoking habits was very similar for the squamous and oat or small cell groups.

TABLE C1

Lung cancer type of lung cancer decedents

Lung Cancer Type	Male				
	Source of Information				
	Histology only	Cytology only	Both	Total	Percent of Total classified
Squamous carcinoma	95	89	44	228	51.7
Oat or small cell carcinoma	36	24	17	77	17.5
Adenocarcinoma	14	1	0	15	3.4
Mixed or other	2	0	0	2	0.5
No lung cancer microscopically confirmed	4	96	19	119	26.7
Total classified	151	210	80	441	100.0
Without histology or cytology				133	
No information for decedent found in records				65	
Overall total				639	

	Female				
Squamous carcinoma	26	8	1	35	36.1
Oat or small cell carcinoma	15	11	5	31	32.0
Adenocarcinoma	6	0	0	6	6.2
Mixed or other	1	0	0	1	1.0
No lung cancer microscopically confirmed	1	16	7	24	24.7
Total classified	49	35	13	97	100.0
Without histology or cytology				39	
No information for decedent found in records				18	
Overall total				154	

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TABLE C2

Relationship between lung cancer type and smoking habits

Smoking habits (taken from hospital records)	Male			
	Squamous	Oat or small cell	Adeno-carcinoma	Total
Non-smoker	14 (7.5%)	3 (4.9%)	2(14.3%)	19 (7.3%)
Manufactured cigarette smoker	160(85.6%)	54(88.5%)	12(85.8%)	226(86.3%)
Hand-rolled	10 (5.4%)	4 (6.6%)	0 (0.0%)	14 (5.3%)
Pipe or cigar	1 (0.5%)	0 (0.0%)	0 (0.0%)	1 (0.4%)
Ex-smoker	2 (1.1%)	0 (0.0%)	0 (0.0%)	2 (0.8%)

	Female			
Non-smoker	3(13.6%)	4(17.4%)	1(100.0%)	8(17.4%)
Manufactured cigarette smoker	19(86.3%)	19(82.6%)	0 (0.0%)	38(82.6%)

In view of the findings both that the number of patients with confirmed adenocarcinoma was so low, and that a very substantial proportion of the males who did have adenocarcinoma smoked, it did not seem worthwhile to carry out any further analyses such as recalculating the lung cancer relative risks given in Table 8 looking only at non-adenocarcinoma decedents. The relative risks associated with the various categories of smoking would certainly have turned out to be virtually identical to those given for all lung cancer decedents.

Appendix D - Smoking habits according to the relative compared with those according to the decedent

As stated in section I.5 the smoking habits as reported by the lung cancer decedents when they were in hospital were provided for us, where available, from the hospital notes. As a different questionnaire had been used in hospital from that used to obtain information from the relatives, a direct comparison of exactly the same smoking group classifications was not possible. However it was possible to produce a classification by four broad groups of smoking habit, and the degree of agreement from the two sources is illustrated in Table D1. The table shows that there is a considerable area of agreement as to whether or not the lung cancer decedents had ever smoked manufactured cigarettes, but much less agreement as to whether they had smoked other materials or had been ex-smokers. This latter finding was possibly due to differences in the way the questions had been asked rather than to either the relative or the decedent, when in hospital, giving biassed answers.

It was also possible for us to compare the answers to numbers of cigarettes smoked. As Table D2 shows, the degree of correlation was fairly poor, agreement being reached in only 44% of cases. The disagreement did not, however, appear to consist of a marked bias in any one direction, as can be seen from the overall distributions of smoking level as measured in the two different ways.

Our findings are in broad agreement with those given by Rogot and Reid (1975) who studied a more general population with a larger proportion of non-smokers. They are also similar to those of Todd (1966), who in 1964 interviewed relatives of 193 people who had given information on smoking habits in 1948/50 and had subsequently died. Stocks (1957), however, who compared smoking histories given by male cancer patients and by relatives of the same patients after their death, came to a somewhat different conclusion. He found that widows tended to understate the numbers of cigarettes smoked by their husbands, giving average numbers of cigarettes smoked per week as 136 according to the patient and 104 according to the widow. However they did not give any information as to the distribution of the differences between the two methods.

TABLE D1

Smoking habits of lung cancer decedents as given by relatives compared with those taken from hospital records

Relative	Hospital records								
	Male					Female			
	Non-smoker	Man. cigs	Other	Ex-smoker	Total	Non-smoker	Man. cigs	Ex-smoker	Total
Never smoked	7	3	0	0	10	8	2	0	10
Man. cigs. only	4	212	1	0	217	2	48	1	51
Mixed or other	3	76	21	1	101	-	-	-	
Ex-smoker	12	38	2	2	54	2	4	0	6
Total	26	329	24	3	382	12	54	1	67

TABLE D2

Number of manufactured cigarettes smoked a day by lung cancer decedents as given by relatives compared with that taken from hospital records

Relative	Hospital records							
	Male				Female			
	1-12	13-22	23+	Total	1-12	13-22	23+	Total
1-12	17	21	19	57	6	4	1	11
13-22	18	37	28	83	7	11	0	18
23+	10	34	45	89	1	8	5	14
Total	45	92	92	229	14	23	6	43

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Appendix E - Details of statistical method

This appendix gives full details of the method, outlined in section I.6, used to derive a single relative risk estimate from a number of 2 x 2 sub-tables and to test the estimate for significance and consistency.

We consider first the single 2 x 2 sub-table with observed data as follows:

	Factor		
	Positive	Negative	Total
Dead	d_1	d_2	D
Living	l_1	l_2	L
Total	P	M	T

If the true proportion of positive is y in the dead and z in the living, and r is the relative risk it follows that the 2 x 2 sub-table of expected proportions can be written in terms of z and r as follows:

	Factor	
	Positive	Negative
Dead	rz/(1-z+rz)	(1-z)/(1-z+rz)
Living	z	(1-z)

Thus the log-likelihood, L, associated with the observed data is given by the expression:

$$L = d_1 \log r + P \log z + M \log (1-z) - D \log (1-z+rz) \qquad (1)$$

We wish to find the maximum of L in 3 situations:

a) r known to be 1

If r = 1, L collapses to P log z + M log(1-z) and is a maximum with respect to z when z = P/T. The value of this maximum, L_1', is given by:

$$L_1' = P \log P + M \log M - T \log T \qquad (2)$$

b) r maximum likelihood for the single 2 x 2 sub-table

L is a maximum with respect to r and z simultaneously when both dL/dr = 0 and dL/dz = 0 hold. This occurs when $z = l_1/L$ and $r = (d_1 l_2)/(d_2 l_1)$. Here the value of the maximum, L_{MAX}', is:

$$L'_{MAX} = d_1 \log d_1 + d_2 \log d_2 + l_1 \log l_1 + l_2 \log l_2 - D \log D - L \log L \quad (3)$$

It is easy to show that if one or more of the row or column totals (D, L, P or M) are zero, then $L'_1 = L'_{MAX}$. In this situation, we define the sub-table as contributing no "useful" information.

c) r known, but not equal to 1

If r is known, L is a maximum for that z which solves dL/dz = 0 or

$$\frac{P}{z} - \frac{M}{1-z} - \frac{D(r-1)}{1-z+rz} = 0$$

Rearranging this yields a quadratic equation in z

$$Az^2 + Bz + C = 0$$

where A = Lv, B = T+(D-P)v, C = -P and v = r-1.

Although this quadratic has two solutions, only the first

$$z_1 = (-B + \sqrt{B^2-4AC})/2A$$

lies in the range (0,1) and is acceptable (see Lemma 1 at the end of this Appendix). Substituting z_1 into equation 1 gives the value of L'_r, the maximum log-likelihood with r known.

Thus, for a single "useful" 2 x 2 sub-table, significance can be tested, using the likelihood ratio test by taking $2(L'_{MAX} - L'_1)$ as asymptotically χ^2-distributed with 1 d.f. Similarly a test of the adequacy of a "known" value of r can be tested using $2(L'_{MAX} - L'_r)$.

We next consider the case of a number of sub-tables. L_1 and L_{MAX}, as defined in section I.6, can be computed simply by summing (respectively) the values of L'_1 and L'_{MAX} obtained from each useful sub-table.

To find the single value of r best fitting all the sub-tables, with associated log likelihood L_R, we use the fact that, given a particular r, the log likelihood can be calculated from the sum over the useful sub-tables of the values of L'_r. Thus finding L_R simply involved maximizing this sum with respect to the single variable r.

Lemma

It is required to prove that z_1 lies inside and z_2 outside the range (0,1) where $z_1 = (-B + \sqrt{B^2-4AC})/2A$, $z_2 = (-B - \sqrt{B^2-4AC})/2A$ and A, B and C are as defined in c) above.

Sub-lemma 1 A + B + C is positive

Proof: $A + B + C = v(L+D-P)+(T-P)$

$= Mv + M$

$= Mr$ which is positive as $r>0$.

Proof of lemma Consider the cases a) $r>1$ b) $0<r<1$ in turn

a) As $r>1$, $v>0$ and it follows that

$$A>0$$
$$4AC<0$$
$$B^2 - 4AC>B^2>0$$

and it follows directly that both z_1 and z_2 are real and that z_1 is positive and z_2 is negative.

By rearranging the expression in z_1 it can be seen that

$z_1<1$ if and only if $B^2-4AC<(2A+B)^2$

i.e. if and only if $0<A + B + C$

which is true by sub-lemma 1.

It follows that z_1 lies inside (0,1) and z_2 outside.

b) As $0<r<1$, $-1<v<0$ and it follows that

$$A<0$$
$$4AC>0$$
$$B^2 - 4AC<B^2$$

As $(B^2-4AC) - (2A+B)^2 = -4A(A+B+C)$ which is positive (using sub-lemma 1) it follows that both z_1 and z_2 are real and positive and that $z_2>z_1$.

By rearranging the expressions in z_1 and z_2 it follows that

$z_1<1$ and $z_2<1$ are both true if and only if $B^2-4AC>(2A+B)^2$

which we have already shown to be true.

Thus, again, z_1 lies inside (0,1) and z_2 outside.

TABLE F1

Supplement to Tables in Section I.8; numbers of deaths and in the living population by age, social class and district

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
AGE									
35-44	14	6	43	18	7	3	750	750	800
45-54	85	28	190	78	27	12	785	785	795
55-64	218	96	337	189	48	32	550	550	693
65+	301	400	-	-	68	171	478	-	770
SOCIAL CLASS									
I & II	49	11	57	25	3	3	304	260	175
III	257	141	289	140	28	9	1313	1157	642
IV	122	73	127	47	17	8	454	386	391
V	96	78	76	62	17	11	293	208	276
Other	92	226	22	11	10	42	189	74	179
Housewife	-	-	-	-	75	144	-	-	1385
DISTRICT									
Eston	65	42	64	23	12	18	422	348	485
Stockton	100	99	106	33	27	38	425	343	485
ex-Stokesley	14	3	15	8	4	2	165	139	208
Rest of Teesside	306	283	244	133	68	100	820	641	949
Hartlepool	77	86	86	57	27	54	454	389	513
Urban Districts	64	37	56	31	12	6	277	225	318

TABLE F2

Supplement to Tables in Section I.9; numbers of deaths and in the living population by smoking group, by level of inhalation and by age of starting to smoke

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
SMOKING GROUP									
Never smoked	25	47	81	27	41	120	510	428	1538
Man. cigs. only									
1-12 a day	81	97	84	50	31	25	284	195	486
13-22 a day	125	75	112	53	44	21	429	372	621
23+ a day	131	68	87	53	27	24	237	218	151
Mixed smokers	102	64	110	19	-	-	380	315	-
Other smokers	63	65	61	19	-	-	328	251	-
Ex-smokers	89	118	87	35	7	28	417	308	262
INHALING HABITS	(Numbers refer to manufactured cigarettes only smokers)								
None	21	23	17	4	13	14	74	48	207
Little	40	38	39	24	25	9	157	125	321
Fair Amount	92	82	82	50	29	16	268	231	301
Lot	169	105	217	64	33	30	415	367	317
AGE OF STARTING TO SMOKE	(Numbers refer to manufactured cigarettes only smokers)								
<15	44	38	25	22	7	4	165	119	109
15-19	160	118	120	75	39	21	485	435	504
20-24	52	23	45	11	18	9	161	136	229
25+	24	15	22	12	27	26	75	57	274

TABLE F3

Supplement to Tables in Section 10a; numbers of filter smokers (F) and of plain smokers (P) in the living population by levels of various factors studied (with result of age-standardised significance tests (p) of differences in distribution)

Factor studied/ Level of factor	Male		Female	
	F	P	F	P
DISTRICT				
Eston	106	69	169	37
Stockton	91	42	157	24
ex-Stokesley	37	16	82	10
Rest of Teesside	205	106	304	59
Hartlepool	107	45	186	29
Urban Districts	65	34	90	10
p	Not sig.		Not sig.	
SOCIAL CLASS				
I + II	68	14	65	4
III	315	156	247	28
IV	124	58	175	34
V	70	61	97	25
Other	33	23	370	71
Housewife	-	-	31	7
p	<0.001		<0.05	
COFFEE (cups per day)				
None	284	181	347	82
1-5	303	118	660	79
6+	41	12	90	9
p	<0.001		<0.01	

Factor studied/ Level of factor	Male		Female	
	F	P	F	P
TEA (cups per day)				
None	18	11	47	2
1-6	323	155	488	85
6+	269	146	452	82
p	Not sig.		Not sig.	
ALCOHOL FREQUENCY				
Most days/2-3 times a week	343	193	284	58
Once a week/Once a month	144	60	281	37
Less often/Not at all	122	59	313	74
p	<0.05		<0.05	
DRINK USUALLY TAKEN				
Beer	606	265	423	92
Not beer/non-drinker	103	47	564	78
p	Not sig.		Not sig.	
Spirits	67	23	292	27
Not spirits/non-drinker	552	289	695	143
p	Not sig.		Not sig.	
Wine	35	9	136	13
Not wine/non-drinker	574	303	851	157
p	Not sig.		Not sig.	

TABLE F3 (continued - 1)

Supplement to Tables in Section I.10a; numbers of filter smokers (F) and of plain smokers (P) in the living population by levels of various factors studied (with result of age-standardised significance tests (p) of differences in distribution)

Factor studied/ Level of factor	Male		Female		Factor studied/ Level of factor	Male		Female	
	F	P	F	P		F	P	F	
LEVEL OF EXERCISE					EXPOSURE TO FUMES				
A lot	203	117	361	59	Ever exposed to gas or fumes	171	97	30	
Moderate	246	105	422	73	Not exposed	437	214	948	1
Little or none	161	90	204	38	p	Not sig.		Not sig.	
p	Not sig.		Not sig.						
					EXPOSURE TO DUST				
OBESITY INDEX									
					Ever worked in dusty job	317	196	141	
>3.6	172	89	167	33	Never worked	292	116	847	1
3.2 - 3.6	299	130	394	61	p	<0.01		<0.001	
<3.2	123	80	405	73					
p	<0.1		Not sig.		POLLUTION LEVEL AT HOME ADDRESS*				
MORNING COUGH									
					High	46	32	108	
Usually coughs first thing a.m. in winter and summer	246	170	237	61	Intermediate	285	140	409	7
					Low	103	48	152	
Does not	366	141	751	100	p	Not sig.		Not sig.	
p	<0.001		<0.01						
DEATH OF RELATIVE									
Close relative died of bronchitis, cancer, heart attack or stroke	212	112	391	71					
Did not	397	100	595	89					
p	Not sig.		Not sig.						

* Estimates available for Teesside C.B. only

TABLE F4

Supplement to Tables in Section I.10b; numbers of living people for whom information was self-reported (S) or reported by others (O) by levels of various factors studied (with result of age-standardised significance tests of differences in distribution)

Factor studied/ Level of factor	Male		Female	
	S	O	S	O
MAIN SMOKING GROUP				
Never smoked	213	297	880	578
Man. cigs. only 1-12 a day	121	140	304	175
13-22 a day	180	242	307	209
23+ a day	109	128	95	56
Mixed smokers	210	186	-	-
Other smokers	148	165	-	-
Ex-smokers	221	179	160	98
p	<0.001		Not sig.	
FILTER/PLAIN (Man. cig. only smokers)				
Plain	133	176	109	58
Filter	276	329	597	382
p	Not sig.		Not sig.	
INHALING HABITS (Man. cig. only smokers)				
Lot	183	232	202	115
Fair Amount	115	151	188	133
Little	80	77	201	120
None	30	44	135	72
p	Not sig.		Not sig.	

Factor studied/ Level of factor	Male		Female	
	S	O	S	O
SOCIAL CLASS				
I + II	140	184	104	74
III	613	747	332	229
IV	251	233	246	165
V	138	162	186	85
Other	108	90	110	74
Housewife	-	-	873	551
p	<0.05		<0.1	
COFFEE (cups per day)				
None	539	613	697	452
1-5	544	729	1051	652
6+	61	71	108	68
p	Not sig.		Not sig.	
TEA (cups per day)				
None	43	63	68	39
1-5	896	794	1071	667
6+	511	568	729	466
p	Not sig.		Not sig.	

Supplement to Tables in Section I.10b; numbers of living people for whom information was self-reported (S) or reported by others (O) by levels of various factors studied (with result of age-standardised significance tests of differences in distribution)

Factor studied/ Level of factor	Male		Female	
	S	O	S	O
ALCOHOL FREQUENCY				
Most days/2-3 times a week	703	751	389	269
Once a week/Once a month	256	329	418	280
Less often/Not at all	288	335	1052	626
p	Not sig.		Not sig.	
DRINK USUALLY TAKEN				
Beer	990	1114	604	390
Not beer/non-drinker	260	301	1255	788
p	Not sig.		Not sig.	
Spirits	81	100	329	179
Not spirits/non-drinker	1169	1315	1530	999
p	Not sig.		<0.1	
Wine	118	136	405	256
Not wine/non-drinker	1131	1279	1454	922
p	Not sig.		Not sig.	
EXERCISE TAKEN				
A lot	434	472	572	365
Moderate	484	579	807	496
Little or none	332	384	480	314
p	Not sig.		Not sig.	
OBESITY INDEX				
>3.6	386	426	486	257
3.2 - 3.6	583	673	748	469
<3.2	262	240	582	402
p	Not sig.		<0.05	

Factor studied/ Level of factor	Male		Female	
	S	O	S	O
MORNING COUGH				
Usually coughs first thing a.m. in winter & summer	404	449	317	185
Does not	846	983	1543	991
p	Not sig.		Not sig.	
DEATH OF RELATIVE				
Close relative died of bronchitis, cancer, heart attack or stroke	471	492	784	368
Did not	773	916	1069	807
p	Not sig.		<0.001	
EXPOSURE TO FUMES				
Ever exposed to gas or fumes	405	364	74	32
Not exposed	841	1054	1784	1144
p	<0.001		<0.1	
EXPOSURE TO DUST				
Ever worked in dusty job	721	845	269	104
Never worked	528	768	1591	1073
p	<0.001		<0.001	
POLLUTION LEVEL AT HOME ADDRESS+				
High	116	154	228	102
Intermediate	527	549	735	465
Low	215	228	286	222
p	Not sig.		<0.001	

+ Estimates available for Teesside C.B. only

TABLE F5

Supplement to Tables in Section I.11; numbers of decedents and in the living population by other aspects of the smoking habit

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
DETAILED SMOKING GROUP									
Never smoked	25	47	61	27	41	120	510	428	1638
Man. cig. only smokers - filter	118	91	136	58	71	45	610	438	988
Man. cig. only smokers - plain	219	147	127	98	31	25	320	247	170
Hand-rolled only	36	14	26	7	-	-	147	133	-
Pipe only	23	47	25	11	-	-	116	65	-
Cigars only	0	2	2	0	-	-	26	22	-
Mixed "others" only	4	2	5	1	-	-	37	31	-
Man. cigs. and "others" now	62	28	66	24	-	-	231	196	-
Man. cigs. now, "others" once	9	11	13	8	-	-	31	24	-
Hand-rolled now, man. cigs. once	17	17	22	10	-	-	44	36	-
Pipe now, man. cigs. once	7	7	8	5	-	-	25	17	-
Cigar now, man. cigs once	1	0	4	0	-	-	30	25	-
Mixed "others" now, man. cigs. once	6	1	8	1	-	-	19	17	-
Ex-smokers of man. cigs. only									
Gave up ≤ 4 years ago	28	24	13	11	4	7	102	81	110
Gave up 5-8 years ago	11	15	9	5	1	6	43	31	38
Gave up 9-18 years ago	15	22	10	7	2	15	86	66	114
Gave up 19+ years ago	8	20	11	4			66	44	
Total	62	81	43	27	7	28	297	221	262
Other ex-smokers	27	35	24	8	-	-	121	88	-

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TABLE F5 (continued - 1)

Supplement to Tables in Appendix A; numbers of decedents and in the living population by other aspects of the smoking habit

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
TYPE OF MANUFACTURED CIGARETTE CURRENTLY SMOKED									
Plain - small	116	92	63	42	14	16	143	103	93
- medium/large	97	53	68	48	13	9	157	129	70
Filter - mini / small	18	22	27	6	16	13	102	86	210
- intermediate/ medium	89	60	101	48	50	26	417	366	642
- king-size	8	9	9	6	3	4	97	89	134
NUMBER OF MANUFACTURED CIGARETTES CURRENTLY SMOKED									
1-7	24	41	24	14	12	9	88	63	195
8-12	52	58	40	34	19	16	168	126	291
13-17	37	16	36	19	16	6	116	96	177
18-22	88	59	77	34	28	15	313	278	344
23-27	22	14	18	7	1	2	53	50	43
28-32	43	25	26	19	11	10	76	66	67
33-47	44	16	32	22	9	10	81	75	38
48+	22	11	11	5	6	2	27	27	3
INHALING HABITS X AMOUNT SMOKED									
1-12 a day - None	14	14	7	4	5	9	42	28	135
- Little	20	25	10	16	13	8	74	55	186
- Fair amount	46	21	17	12	10	2	84	66	99
- Lot	23	22	16	10	3	6	53	39	59

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TABLE F5 (continued - 2)

Supplement to Tables in Appendix A; numbers of decedents and in the living population by other aspects of the smoking habit

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
INHALING HABITS X AMOUNT SMOKED (continued)									
13-22 a day - None	3	5	5	0	7	3	25	16	59
- Little	8	7	13	3	7	1	59	50	118
+ Fair Amount	46	21	46	19	13	7	129	115	167
- Lot	65	38	47	27	16	10	209	184	174
23+ a day - None	4	4	5	0	1	2	7	4	13
- Little	12	4	7	5	5	0	24	20	19
- Fair Amount	30	12	19	19	6	7	53	50	35
- Lot	81	46	154	27	14	15	153	144	84
All man. ctg. smokers - None	21	23	17	4	13	14	74	48	207
- Little	40	36	39	24	26	9	157	125	321
- Fair Amount	92	62	82	50	29	16	206	231	301
- Lot	169	105	217	64	33	30	416	367	317
AGE OF STARTING TO SMOKE X AMOUNT SMOKED									
1-12 a day - <15	10	7	3	4	1	0	37	22	28
- 15-19	61	54	28	24	13	7	244	93	180
- 20-24	21	8	9	6	4	0	74	40	90
- 25+	10	9	6	5	10	13	23	32	167
13-22 a day - <15	15	14	9	5	4	0	70	47	51
- 15-19	61	30	68	28	18	6	244	227	253
- 20-24	21	10	19	1	7	5	74	63	109
- 25+	10	3	9	3	11	8	23	17	89

TABLE F5 (continued - 3)

Supplement to Tables in Appendix A; numbers of decedents and in the living population by other aspects of the smoking habit

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
AGE OF STARTING TO SMOKE X AMOUNT SMOKED (continued)									
23+ a day - <15	19	17	13	13	2	4	58	50	30
- 15-19	64	34	36	26	8	8	118	115	71
- 20-24	16	5	18	4	7	4	35	33	30
- 25+	7	3	7	4	6	5	12	8	18
All man. cig. smokers - <15	44	38	25	22	7	4	165	119	109
- 15-19	160	118	130	75	39	21	485	435	504
- 20-24	52	23	40	11	18	9	161	136	229
- 25+	24	15	22	12	27	28	75	67	274
SMOKING HABITS IN 1969									
Never smoked	25	47	62	19	41	120	514	431	1550
Man. cigs. only - 1-12 a day	77	103	68	31	33	23	279	216	594
- 13-22 a day	136	79	127	34	41	27	518	448	601
- 23+ a day	142	78	101	38	20	24	281	252	140
"Mixed" smokers	61	30	62	21	-	-	214	173	-
"Other" smokers	89	93	97	24	-	-	427	326	-
Ex-smokers	66	96	40	16	3	23	311	223	168

TABLE F5 (continued - 4)

Supplement to Tables in Appendix A ; numbers of decedents and in the living population by other aspects of the smoking habit

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
SMOKING HABITS IN 1964									
Never smoked	25	17	63	28	42	120	518	434	1568
Man. cigs. only - 1-12 a day	71	82	62	44	34	23	308	244	668
- 13-22 a day	151	93	146	54	37	29	566	486	453
- 23+ a day	172	114	107	64	30	24	303	263	112
"Mixed" smokers	52	31	64	30	-	-	198	156	-
"Other" smokers	94	90	82	38	-	-	391	293	-
Ex-smokers	34	66	34	22	3	18	252	181	144
SMOKING HABITS IN 1954									
Never smoked	26	47	65	28	42	25	547	463	1620
Man. cigs. only - 1-12 a day	74	86	62	45	40	123	362	283	727
- 13-22 a day	161	97	164	70	37	33	697	510	404
- 23+ a day	183	138	116	70	27	21	325	270	98
"Mixed" smokers	55	39	61	31	-	-	198	154	-
"Other" smokers	71	77	70	21	-	-	339	255	-
Ex-smokers	19	33	26	9	12	2	152	112	83

TABLE F6

Supplement to Tables in Appendix B; numbers of decedents and in the living population by some personal and environmental factors

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
COFFEE (cups per day)									
None	416	392	352	100	77	143	1152	909	1116
1-5	174	128	203	88	67	70	1273	1043	1659
6+	10	5	10	3	4	2	132	128	172
TEA (cups per day)									
None	7	5	5	6	0	0	92	82	93
1-5	303	267	260	138	63	101	1427	1132	1694
6+	298	255	304	140	88	115	1043	871	1162
ALCOHOL FREQUENCY									
Most days/2-3 times a week	383	286	316	169	36	41	1398	1199	630
Once a week/Once a month	85	96	113	60	26	29	569	471	682
Less often/Not at all	142	145	139	65	87	148	594	413	1641
DRINK USUALLY TAKEN									
Beer	509	406	470	231	58	68	2028	1719	964
Not beer or non-drinker	107	123	101	54	94	150	534	365	1952
Spirits	58	51	58	36	29	38	244	206	644
Not spirits or non-drinker	560	478	513	249	121	180	2318	1878	2312
Wine	17	13	18	16	25	31	173	134	492
Not wine or non-drinker	599	518	553	269	125	187	2389	1950	2464

TABLE FG (continued - 1)

Supplement to Tables in Appendix B ; numbers of decedents and in the living population by some personal and environmental factors

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
LEVEL OF EXERCISE									
A lot	250	139	203	89	57	52	874	768	906
Moderate	214	163	188	110	63	66	1014	818	1273
Little or none	147	224	178	85	28	100	874	498	774
OBESITY INDEX									
>3.6	127	91	203	103	38	58	782	656	734
3.2 - 3.6	272	221	248	121	43	56	1216	1023	1186
<3.2	180	173	102	47	66	88	493	350	948
MORNING COUGH									
Usually coughs first thing a.m. in winter & summer	404	413	269	128	85	117	829	664	477
Does not	194	105	297	153	81	95	1730	1417	2478
DEATH OF RELATIVE									
Close relative died of bronchitis, cancer, heart attack or stroke	278	235	322	167	75	98	937	775	1120
Did not	299	268	233	109	69	113	1615	1300	1825
PARENT DIED OF									
Lung Cancer	18	3	5	3	1	2	66	61	74
Bronchitis	29	36	24	17	0	12	127	107	161
Heart Attack	52	32	124	40	13	11	258	228	279
Stroke	27	21	37	42	5	4	111	98	172
Other Cancer	78	42	70	30	25	19	276	239	307

TABLE F6 (continued - 2)

Supplement to Tables in Appendix B; numbers of decedents and in the living population by some personal and environmental factors

Factor studied/ Level of factor	Decedents						Living		
	Male				Female		Male		Female
	Lung Cancer	Chronic Bronchitis	Coronary Heart Dis.	Cerebro-vascular Dis.	Lung Cancer	Chronic Bronchitis	35+	35-64	35+
SIBLING DIED OF									
Lung Cancer	35	14	8	6	9	6	36	21	47
Bronchitis	17	40	7	8	7	18	21	14	33
Heart Attack	33	57	74	35	10	29	66	43	100
Stroke	17	21	13	17	6	13	20	11	34
Other Cancer	63	56	36	31	142	142	98	57	24
EXPOSURE TO FUMES									
Ever exposed to gas or fumes	214	168	173	81	9	6	731	685	86
Not exposed	393	358	390	202	139	210	1823	1491	2857
EXPOSURE TO DUST									
Ever worked in dusty job	361	324	308	140	23	29	1314	1052	357
Never worked	281	204	280	130	126	189	1243	1027	2589
TYPES OF DUSTY JOB									
Coalmine	15	27	17	5	-	-	58	37	-
Other mine	17	25	20	6	-	-	56	38	-
Foundry	54	73	55	30	-	-	200	161	-
Asbestos	8	1	8	0	-	-	14	13	-
Other dusty job	300	270	244	121	-	-	1029	828	-
POLLUTION LEVEL AT HOME ADDRESS+									
High	116	120	93	41	30	40	285	198	320
Intermediate	247	215	227	90	54	79	1040	842	1175
Low	107	68	93	48	28	30	362	294	493

+ Estimates available for Teesside C.D. only

Index to Tables

Table Number	MAIN TABLES	Page
1	Trends in tar yields between 1965 and 1973 in the United Kingdom	5
2	Living population by age at interview and sex	15
3	Living population by district and sex	15
4	Decedents studied in Cleveland County	17
5	Success rate for following up decedents	17
6	Deaths studied by age at death, sex and cause of death	27
7	Relative risks of mortality by age (unstandardised), by social class and by district (standardised for age and smoking group)	29
8	Relative risk of mortality (standardised for age) by smoking group	31
9	Relative risk of mortality (standardised for age and level of smoking) of manufactured cigarette only smokers by level of inhalation and by age of starting to smoke	33
10	Distribution of filter and plain smokers in the decedents and in the living population	35
11	Relative risk of mortality (standardised for age, amount smoked and other smoking characteristics) of filter as compared with plain smokers	35
12	Relative risk of mortality (standardised for age, amount smoked and other non-smoking characteristics) of filter as compared with plain smokers	36
13	Relative risk of mortality of filter to plain smokers standardised for age and smoking level based on 1969 smoking information	38
14	Relative risk of mortality of filter to plain smokers standardised for age and smoking level based on most recent smoking information and corrected for bias	39
15	Relative risk of mortality of continuing plain smokers, continuing filter smokers and switchers from plain to filter based on smoking habits in 1954, 1964 and 1969	40
	APPENDIX A	
A1	Relative risk of mortality (standardised for age) by detailed smoking group	49
A2	Relative risk of mortality (standardised for age) by type of manufactured cigarette smoked	51
A3	Relative risk of mortality (standardised for age) by number of manufactured cigarettes currently smoked	51

Table Number		Page
A4	Relative risk of mortality (standardised for age) by inhaling and by number of manufactured cigarettes smoked	53
A5	Relative risk of mortality (standardised for age) by age of starting to smoke and by number of manufactured cigarettes smoked	54
A6	Relative risk of mortality (standardised for age) by smoking habits as at 1969, 1964 and 1954	55
	APPENDIX B	
B1	Relative risk of mortality (standardised for age and smoking group) by coffee and tea consumption, by alcohol frequency and by sort of drink usually taken	57
B2	Relative risk of mortality (standardised for age and smoking group) by lack of exercise, obesity index, presence of morning cough and whether close relative had died of related diseases	59
B3	Relative risk of mortality (standardised for age and smoking group) by whether parent or sibling died of bronchitis, lung cancer, heart attack, stroke or other cancer	61
B4	Relative risk of mortality (standardised for age and smoking group) by exposure to dust, fumes or pollution	63
	APPENDIX C	
C1	Lung cancer type of lung cancer decedents	65
C2	Relationship between lung cancer type and smoking habits	66
	APPENDIX D	
D1	Smoking habits of lung cancer decedents as given by relatives compared with those taken from hospital records	69
D2	Number of manufactured cigarettes smoked a day by lung cancer decedents as given by relatives compared with that taken from hospital records	69
	APPENDIX F	
F1	Numbers of deaths and in the living population by age, social class and district	74
F2	Numbers of deaths and in the living population by smoking group, by level of inhalation and by age of starting to smoke	75
F3	Numbers of filter smokers and of plain smokers in the living population by levels of various factors studied	76

Table Number		Page
F4	Numbers of living people for whom information was self-reported or reported by others by levels of various factors studied	78
F5	Numbers of decedents and in the living population by other aspects of the smoking habit	80
F6	Numbers of decedents and in the living population by some personal and environmental factors	85

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TABLE OF CONTENTS

TABLE OF CONTENTS

Tab #	Author's Name	Title
1	Doll, R.	A Study of the Aetiology of Carcinoma of the Lung
2	Doll, R.	Cancer of the Lung (Smoking and Carcinoma of the Lung)
3	Graham, S.	Cancer of the Lung Related to Smoking Behavior
4	Bross, I.D.J. 67	Toward a Less Harmful Cigarette Effect of Filter Cigarettes on the Risk of Lung Cancer
5	Bross, I.D.J.	Risks of Lung Cancer in Smokers Who Switch to Filter Cigarettes
6	Anonymous	How Do Filter-Tip Smokers End Up
7	Wynder, E.L.	The Epidemiology of Lung Cancer (Recent Trends)
8	Wynder, E.L.	Lung Cancer in Women (Present and Future Trends)
9	Wald, N.J.	Mortality from Lung Cancer and Coronary Heart-Disease in Relation to Changes in Smoking Habits
10	Anonymous	Puff Profile Sifts Smokers at Cancer Risk
11	Anonymous	With Filter-Tips, Cancer is Down, Heart Disease Up
12	Anonymous	Low-Tar Cigarettes (A Little Less Harmful)
13	Anderson, W.H.	Quantification of Smoking in Patients with Smoking Related Disease
14	Hammond, E.C.	Tar and Nicotine Content of Cigarette Smoke in Relation to Death Rates
15	Marano, H.	Women Smoking More (Lung Cancer Rates Up)
16	Stellman, S.D.	Preventive Potential of Low-Tar Cigarettes
17	Auerbach, O.	Changes in Bronchial Epithelium in Relation to Cigarette Smoking, 1955-1960 vs. 1970-1977
18	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part I Introduction to the Whole Report)
19	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part I Introduction of Part I)
20	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part I The Living Sample)
21	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part I Mortality by Age, Sex, Social Class and District)
22	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Mortality by Some Principal Aspects of the Smoking Habit)
23	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part I Mortality by Filter and Plain Smoking)
24	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Summary of Main Findings)
25	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Mortality by Other Aspects of Smoking Habit)
26	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part I Mortality by Some Personal and Environmental Factors)
27	Dean, G.	Report on a Second Mortality Retrospective Study in North-East England (Part I Distribution of Type of Lung Cancer Found)
28	Dean, G.	Report on a Second Mortality Retrospective Study in North-East England (Part I Smoking Habits According to the Relative Compared with Those According to the Decedent)
29	Dean, G.	Report on a Second Mortality Retrospective Study in North-

different authors

		East England (Part I Details of Statistical Method)
30	Wynder, E.L.	Impact of Long-Term Filter Cigarette Usage on Lung and Larynx Cancer Risk
31	~~Auerbach, O.~~	Bronchial Epithelium and Cigarette Smoking
32	Kunze, M.	Smoking Habits of Lung Cancer Patients (Time of Consumption and Tar Contents of Smoked Brands)(Translated from German)
33	Vutuc, C.	Tobacco Smoking and Lung Cancer in Women (Relative Risk for Kreyberg Group I and II)(Translated from German)
34	Auerbach, O.	Changes in Bronchial Epithelium in Relation to Cigarette Smoking, 1955-1960 vs. 1970-1977
35	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part 2 Discussion)
36	Dean, G.	Report on a Second Retrospective Mortality Study in North-East England (Part 2 Factors Affecting Mortality in the Study Districts, 1963-72)
37	Hawthorne, V.M.	Smoking and Health (The Association Between Smoking Behaviour, Total Mortality, and Cardiorespiratory Disease in West Central Scotland)
38	Vutuc, C.	Exposure to Tar by Smoking Bronchial Carcinoma Patients and by Members of a Control Group (Translated from German)
39	Hammond, E.C.	Origins of Human Cancer (Book a Incidence of Cancer in Humans(Some Recent Findings Concerning Cigarette Smoking))
40	Wynder, E.L.	Smoking and Health (Modifying the Risk for the Smoker (Part I General Aspects of the Less Harmful Cigarette (The Epidemiology of the Less-Harmful Cigarette)))
41	Anderson, W.H.	Proceedings of the Fifth Workshop Conference (Relation of Smoking to Cardiopulmonary Disease)
42	Vutuc, C.	Social Class and Lung Cancer (Quantitative and Qualitative Aspects of Cigarette Smoking)
43	Kunzie, M.	A Safe Cigarette (Session I Introduction and Epidemiological Trends (Threshold of Tar Exposure (Analysis of Smoking History of Male Lung Cancer Cases and Controls)))
44	Lee, P.N. & Garfinkel	Mortality and Type of Cigarette Smoked
45	Rimington, J.	The Effects of Filters on the Incidence of Lung Cancer in Cigarette Smokers
46	Doll, R.	The Causes of Cancer (Quantitative Estimates of Avoidable Risks of Cancer in the United States Today (Appendix E Trends in Lung Cancer Death Rates in Relation to Cigarette Usage and Tar Yields)))
47	Vutuc, C.	Cigarette Condensate Exposure of Male Bronchogenic Carcinoma Patients in the 41-50 Age Group (Translated from German)
48	Vutuc, C.	Lung Cancer in Men Under Forty (Results of a Controlled Case Study on the Importance of Tobacco Consumption)(Translated from German)
49	Vutuc, C.	Quantification of Cigarette Tar Exposure and Lung Cancer Risk (Translated from German)
50	Vutuc, C.	Cigarette Smoke Condensate Exposure and Occupational History I Female Lung Cancer Patients (Translated from German)

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DOLL, R.

" A STUDY OF THE AETIOLOGY OF CARCINOMA OF THE LUNG"

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DOLL, R.

"CANCER OF THE LUNG (SMOKING AND CARCINOMA OF THE LUNG"

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CANCER OF LUNG RELATED TO SMOKING BEHAVIOR

SAXON GRAHAM, PHD

Detailed observations of the minutiae of smoking behavior of humans suggested the existence of wide variations in this behavior. Simulation of these various models of puffing behavior on an analytic smoking machine showed that significantly different amounts of tobacco tar were retrievable for each. Lung cancer and control patients were then observed to determine whether and the extent to which the cases exhibited high tar-yield smoking models. It was found that risk of lung cancer increases with the mean number of puffs taken per cigarette and with increases in the average length of time taken to smoke a cigarette regardless of age or amount smoked per day. This was also generally true when analyses were carried out specifically for variations in the number of puffs taken per cigarette. The exception to this was observed only where the largest number of puffs were taken per cigarette. Finally, it was shown that taking more puffs towards the end of a cigarette entails a higher risk than puffing regularly, and that the most frequently exhibited puffing patterns, puffing most often at the beginning, carried the lowest risk. We suggest that if these results were upheld in future replications, further evidence would be at hand of a dose-response relationship linking lung cancer and exposure to tobacco tar. Furthermore, these data would suggest that smokers could lower their risk by taking fewer puffs per cigarette, taking them shortly after lighting up, and smoking with only short intervals between puffs.

A GREAT DEAL OF RESEARCH ON VARIOUS populations utilizing various study designs has shown increased risk of lung cancer with increasing exposure to tobacco smoke. Thus, increases in risk have been related to increases in daily amount smoked and duration of smoking in years. This led us to examine the dose-response relationship in a different way. Our detailed observations of individuals smoking cigarettes revealed rather wide variations in smoking behavior patterns. Simulations of these variations via analytic smoking machine showed that substantial differences in tar yield are characteristic of the different models of behavior.[1] In view of the relationship of increasing lung cancer risk with increased amount smoked, one would hypothesize that individuals exhibiting smoking patterns which are high in tar yield would also have higher risks of lung cancer.

If the hypothesis were upheld, dose-response evidence of a different kind would implicate tobacco tar as a carcinogen. Equally important, if certain smoking methods were found to characterize cases more than controls, information might be at hand out of which measures to reduce risk could be fashioned. A large proportion of even heavy smokers do not develop lung cancer. A study of smokers who do and do not develop lung cancer could be useful in developing further knowledge of factors predisposing to and protecting against lung cancer. Such study could involve inhalation patterns, differences in brand smoked, and many other facets of behavior. Our present concern was with risk as related to models of smoking behavior which we had previously examined by smoking machine, specifically patterns of puffing exhibited throughout the time during which cigarettes are smoked.

Observations of individuals smoking cigarettes in public places such as hotel lobbies, bus, railroad, airline, and hospital waiting rooms and wards in the Buffalo area, revealed that a number of variations in behavior are commonly exhibited. There were large differences in the number of puffs taken on given cigarettes by smokers, in the length

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of time taken to consume the cigarette before extinguishing it, and in the length of time taken to smoke a given number of puffs. Moreover, puffing frequency varied at different stages in smoking a given cigarette. The patterns observed could be divided into three: puffing at approximately equal frequency throughout the life of the cigarette, puffing slowly at the beginning and increasing the frequency towards the end of the cigarette, and puffing frequently at the beginning, with gradual diminution in frequency toward the end. Observations of smoking behavior showed that given individuals exhibited a given puffing pattern fairly consistently from one cigarette to another.

These observations led us to simulate the various puffing models via the Ecusta smoking machine to determine whether or not tar yield varied among the different models.[1] Several kinds of experiments showed that:

1. More tar is retrieved when a given number of puffs are smoked over a long rather than a short period of time,

2. Taking most puffs at the end of the cigarette results in the largest tar retrieval,

3. Puffs taken at regular intervals throughout the life of the cigarette give the next largest tar yield, and

4. Taking most puffs at the beginning of smoking a cigarette gives the smallest tar retrieval.

It was found, in addition, that puffs taken at the end of a cigarette yield about twice the amount of tar of puffs taken at the beginning. All of these differences were statistically significant. The finding that puffs taken on shorter butts result in higher tar retrieved is consistent with the findings of Lindsey,[3] Kotin and Falk,[2] and Wynder and colleagues[4–6] on related questions. These findings may be related to the fact that puffs taken on shorter butts have been therefore subject to less filtration and contain more tar as a result. Slow smoking for given numbers of puffs rather than fast smoking would result in shorter butt length for each puff subsequent to the first, providing less filtration and more tar yield. This is because more of the cigarette is burning between puffs in slow smoking. Puffing more frequently at the end of the cigarette than at the beginning implies that more puffs are taken on a shorter butt length than would be true were the larger number of puffs taken at the beginning, providing less filtration per puff and greater tar yield. It should be noted that although the differences in amounts of tar retrieved from various models of smoking behavior by the Ecusta machine were of small magnitude, they were relatively of substantial size. Puffing frequently at the end of the cigarette resulted in 7.4% greater tar retrieval than puffing regularly, and 21.0% more than puffing most at the beginning. Slow smoking resulted in 24.2% greater retrieval than fast smoking. The exposure of lung tissue over many years to even moderate excesses in amounts of tobacco tar from each cigarette smoked could result in a significantly larger aggregate exposure.

METHODS

Once we had observed that there were certain regularities in individual smoking behavior, we initiated the smoking machine studies and studies on humans. The latter consisted in observing individuals smoking cigarettes. Using stop-watches, observers began timing the moment the flame was touched to the cigarette end and concluded timing at the moment of extinguishing the cigarette. The number of puffs taken in each two-minute interval throughout the period of smoking the cigarette were recorded as they were taken, and at the conclusion of smoking a graph was drawn to indicate the smoking pattern for that cigarette. Observations on each cigarette were recorded on a card which is exhibited below.

The observations on which these data were based were obtained on male patients in one solarium at Roswell Park Memorial Institute. The solarium was used by individuals with a variety of disorders; all were observed without prior knowledge of diagnosis or understanding as to whether the patient had or had not recently undergone surgery. After the study was concluded, the patient's chart was examined to determine his diagnosis and whether on the date and time of observation he had recently had surgery. It was felt necessary to ascertain this so that post-operative patients could be analyzed separately from those observed prior to surgery: it was felt necessary to do this because of the possibility that smoking behavior may alter after surgery. The findings reported in this paper

are based on pre-operative observations on 183 men with lung cancer and 161 males with diseases which do not involve the respiratory system or possibly tobacco-related diseases, such as peptic ulcers.

As noted above, the research assistants made their observations blindly without knowing diagnosis or operative status of the patient. They were carefully trained to assure consistency in observation. It was found in pre-tests of the study design that there was some variation in observer records of puffing and other behavior. Because of this, studies were instituted under which all three research assistants would observe the same patient smoking the same cigarette. Subsequently, the records of the assistants were compared and discussed among them and the inaccuracies in one or the other pointed out. Corrections were then made in interpretations as to when puffs were taken and other aspects of the observations. This procedure was continued until there was no longer any difference in the observations of the research assistants. The data reported here were gathered subsequent to this pre-test. In some of the analyses described below, age and amount smoked are taken into consideration. The information on which this was based was gathered in the interviews given all patients immediately after admission to the hospital. These were conducted by trained interviewers without knowledge of symptoms or diagnosis of the patients. The quality of their work was checked periodically by analysis of tape recordings of their interviews.

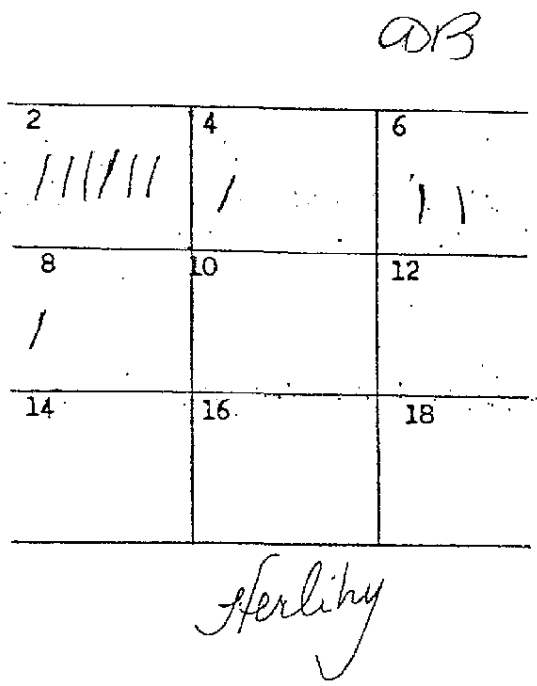

FIG. 1. On one side of the cigarette smoking observation card, a mark was made for each puff taken in each 2 min interval. Thus, in smoking this cigarette, the smoker puffed six times in the first 2 min and once in the second two min.

We are extremely grateful to Dr. John E. Dowd, Statistician of the World Health Organization, Geneva, who designed our computer program.

Table 1 shows that the majority of patients were observed more than once. Indeed, over

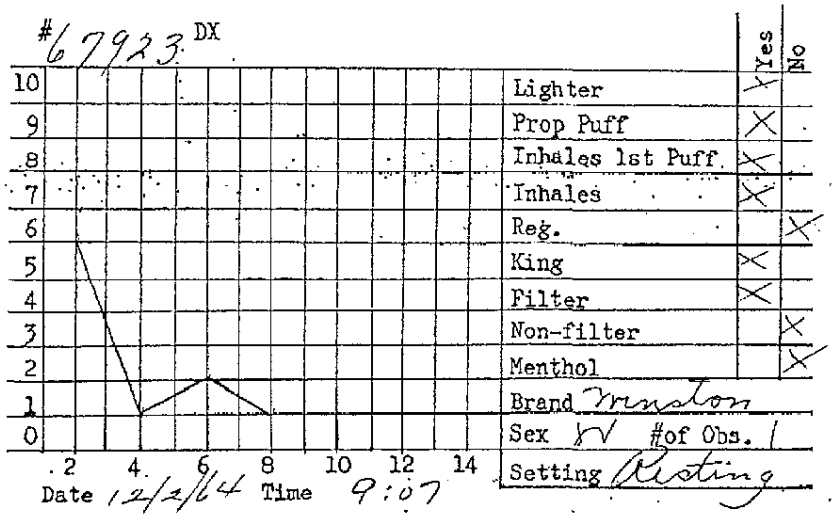

FIG. 2. After completion of observations on one cigarette, a graph of the smoking pattern was drawn using the information recorded on the reverse of the observation card as shown in Fig. 1.

TABLE 1. Numbers of Observations on Cases and Controls

No. of observations	Cases observed		Controls observed	
	No.	%	No.	%
1	27	14.8	34	21.1
2	27	14.8	25	15.5
3	16	8.7	13	8.1
4	20	10.9	12	7.4
5	14	7.7	18	11.1
6–10	42	23.0	35	21.9
11–15	18	9.9	6	3.8
15+	19	10.2	18	11.1
N	183	100.0	161	100.0
$\bar{X}$	6.78		5.96	
SD	6.99		8.31	
SE	1.35		1.60	
TOTAL	1371		1114	

10% of both cases and controls were observed smoking 15 or more cigarettes. About 80% of each were observed smoking 2 or more cigarettes. There was no significant difference in the mean observations taken for lung cancer cases and controls. A total of 1371 observations were made on the 183 cases and 1114 observations on the 161 controls. The distribution of lung cancer cases as compared to controls on amount smoked per day was approximately what would be expected on the basis of previous research. Thus, of the total cases, a substantially larger percentage (47.5%) smoked over one pack of cigarettes per day than was true of controls (28.6%). Smoking distributions by age were similar.

FINDINGS

In general, the findings as to risk of lung cancer were those hypothesized on the basis of the smoking machine studies described above. Patients exhibiting smoking patterns which on the smoking machine experiments yielded large amounts of tar had higher risks of lung cancer. Furthermore, as the amount of tar retrieval associated with a given smoking model increased, so did risk of lung cancer.

Table 2, for example, shows that as the average number of puffs per cigarette taken by patients increases so does risk of lung cancer. About 35% of lung cancer patients took ten or more puffs per cigarette, on the average, as compared to about 30% of controls. Making the ratio of the percentages smoking various numbers of puffs relative to the ratio of the percentages smoking the smallest number of puffs, we find that relative risk of lung cancer increases with the number of puffs taken per cigarette in fairly regular fashion. If it is assumed that exposure to tobacco tar increases as number of puffs taken per cigarette increases, and if exposure to tar is associated with lung cancer, this finding is in the expected direction and suggests a dose-response relationship reminiscent of the increase in risk associated with increases in daily amount smoked. This finding suggests that our analysis of puffing patterns over time should be conducted in categories specific for various average numbers of puffs per cigarette as well as for categories of daily cigarette consumption.

A preliminary examination of our first hypothesis, that the longer the period over which cigarettes are smoked, the greater is the lung cancer risk, is shown in Tables 3a and 3b. Note in Table 3b that the risk increases directly as the mean number of minutes taken to smoke cigarettes increases. The risk for subjects under 60 years of age smoking from 6.0-7.99 minutes is 1.35 times higher than that for subjects smoking over shorter periods on the average. The risk increases to 1.43 for those taking 8.0-9.99 minutes to smoke cigarettes, and it is 3.00 for those who on the

TABLE 2. Mean Puffs Taken per Cigarette, by Cases and Controls

Mean puffs	Cases		Controls		Cases/ controls	Risk relative to 2.0–5.9 puffs $\frac{X}{.73}$
	No.	%	No.	%		
2.0–5.999	20	10.9	24	14.9	.73	1.00
6.0–7.999	55	30.1	45	28.0	1.08	1.48
8.0–9.999	43	23.5	43	26.7	.88	1.21
10.0–11.999	33	18.0	26	16.1	1.12	1.53
12.0–33.999	32	17.5	23	14.3	1.22	1.67
TOTAL	183	100.0	161	100.0		

TABLE 3A. Mean Number of Minutes Required to Smoke One Cigarette, Cases and Controls, by Age

Mean min taken to smoke cig.	<60 yr				60 yr and older				Total			
	Cases		Controls		Cases		Controls		Cases		Controls	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2.0–5.99	12	12.1	19	17.9	9	10.7	11	20.0	21	11.5	30	18.6
6.0–7.99	31	31.3	36	34.0	26	31.0	13	23.6	57	31.1	49	30.4
8.0–9.99	37	37.4	41	38.7	31	36.9	23	41.8	68	37.2	64	39.8
10.0–15.99	19	19.2	10	9.4	18	21.4	8	14.6	37	20.2	18	11.2
TOTAL	99	100.0	106	100.0	84	100.0	55	100.0	183	100.0	161	100.0

average took over ten minutes. The risk for those over 60 increases in a similar but not as regular a fashion.

This could be a function of daily number of cigarettes smoked if we grant that amount smoked is related to average number of minutes spent smoking each cigarette. There is no reason to suspect that this is true, and Table 4, which examines the question by amount smoked, shows roughly the same thing as previously observed. Thus, risk increases more or less regularly with average minutes smoking per cigarette for those consuming one pack or less of cigarettes per day and for those smoking more than one pack per day. The increases in risk are more regular and the effect is more enhanced in the group consuming the larger amount of cigarettes per day.

We have already seen that risk increases with mean number of puffs taken per cigarette making it necessary to analyze speed of smoking by number of puffs taken. Table 5 examines the risk for those taking less than 8.0 minutes to smoke a cigarette, on the average, and those taking 8.0 minutes or longer specifically by mean number of puffs taken per cigarette. Observe that the risk for the longer period of smoking ranges from 1.38 to 2.34 times that for the shorter period of smoking in each category of mean puffs taken from less than 7 to 9.0-9.9. It is interesting that the risks for those smoking 10.0-10.9 puffs on the average are almost identical, and that a reversal of effect is seen for those taking more than 11 puffs. We suggest that this may be related to the fact that in order to take, for example, 12 puffs in 10 minutes, it is necessary that they be of very small smoke volume, so small that it is possible that only small amounts reach the lungs. A substantially larger smoke volume is possible if the 12 puffs are taken over a shorter period, for example, 6 minutes, thus possibly increasing exposure of the lungs substantially and raising lung cancer risk. This, of course, is a tentative suggestion only, and its validity should be examined in future experiments utilizing different volumes of puffs on smoking machines as well as case-control observation.

Table 6 examines the related question as to whether risk of lung cancer increases with increases in the number of puffs taken towards the end of the cigarette. It will be recalled that smoking machine studies of three models of cigarette puffing showed the least tar retrieval from cigarettes puffed most frequently at the beginning of the smoking period, an

TABLE 3B. Relative Risk Associated with Variations in Average Time Required to Smoke Cigarettes, by Age

Mean min taken to smoke cig.	<60 yr		60 yr and older		Total	
	Cases/controls	Risk relative to that for 2.0–5.9 min $\frac{X}{.68}$	Cases/controls	Risk relative to that for 2.0–5.9 min $\frac{X}{.54}$	Cases/controls	Risk relative to that for 2.0–5.9 min $\frac{X}{.62}$
2.0–5.99	.68	1.00	.54	1.00	.62	1.00
6.0–7.99	.92	1.35	1.31	2.43	1.02	1.65
8.0–9.99	.97	1.43	.88	1.63	.93	1.50
10.0–15.99	2.04	3.00	1.47	2.72	1.80	2.90